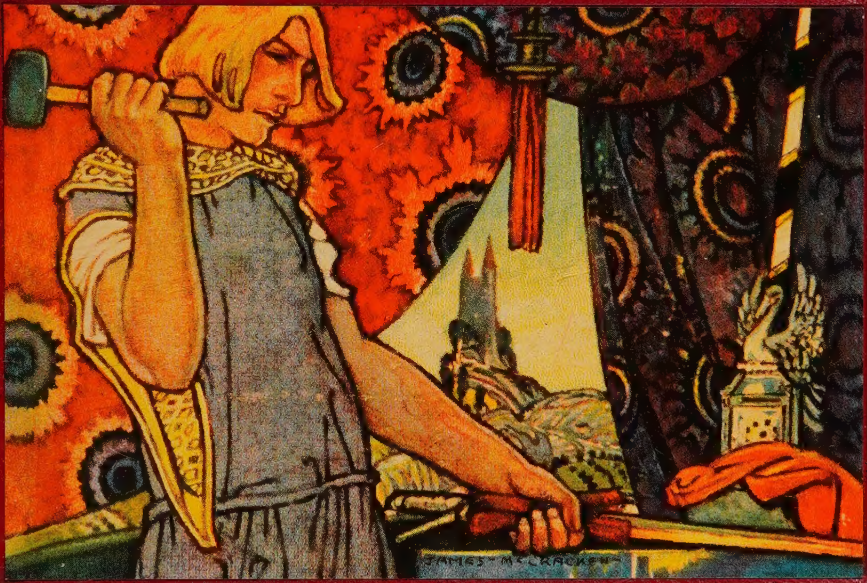
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Volume II

INVENTION AND INDUSTRY

Into the dust of the making of man
Spirit was breathed when his life began,
Lifting him up from his low estate,
With masterful passion, the wish to create.
Van Dyke

EDITOR'S INTRODUCTION

"SCIENCE, Pilot of Industry, Conqueror of Disease, Multiplier of the Harvest, Explorer of the Universe, Revealer of Nature's Laws, Eternal Guide to Truth."

From the inscription on the National Academy of Sciences, Washington, D. C.

MAN'S perpetual struggle to control his environment through the application of principles which science has taught him, forms one of the most thrilling chapters in the book of human progress. Volume One has already given you a picture of his early gropings toward the light. The following pages are a further development of this theme. They tell the story of man's emancipation from the physical slavery of pre-machine days. They provide a panorama of the basic inventions which introduced the Machine Age, as well as of the multitude of machines, devices, industries, and occupations which our modern civilization finds needful.

Without the guiding genius of man, machines and industry are as nothing. Oftentimes a portrait of man, the inventor and scientist, himself, is more truly representative than a description of his discoveries and inventions. You will accordingly find throughout these chapters biographical sketches of key men in the world of science. Necessarily brief, these flashes from worth-while human histories contain a world of inspiration to the thoughtful reader. Whose imagination is not stirred by the romance of science as expressed in the researches of a Franklin, a Pasteur, or an Edison?

Thought of the critical situation in which a great city would find itself should its supplies be cut off even for a week or two, focusses attention on the essential importance of foods and their production and distribution. A generous section has been devoted to a consideration of this salient topic. The geographical significance alone of this subject makes it worthy material for study.

Restless, never-ceasing movement characterizes this modern world of ours. In industry, in invention, progress is the guiding principle. Man's inventive genius is forever posing new problems for industry to solve. It is evident that in such a world of change, no single volume, however carefully watched and frequently revised, can present every subject as fully and elaborately as might be desired. For this reason, detail has been minimized wherever possible, and attention has been centered on broad general principles, illustrating them by description and picture.

It is hoped that from the setting forth of these principles, with their examples in everyday practice, the reader will gain a new interest in the machines, processes, and industries which minister to his comfort and convenience, and an intelligent background for his appreciation of future progress in invention and industry.

Walter L. Munroe

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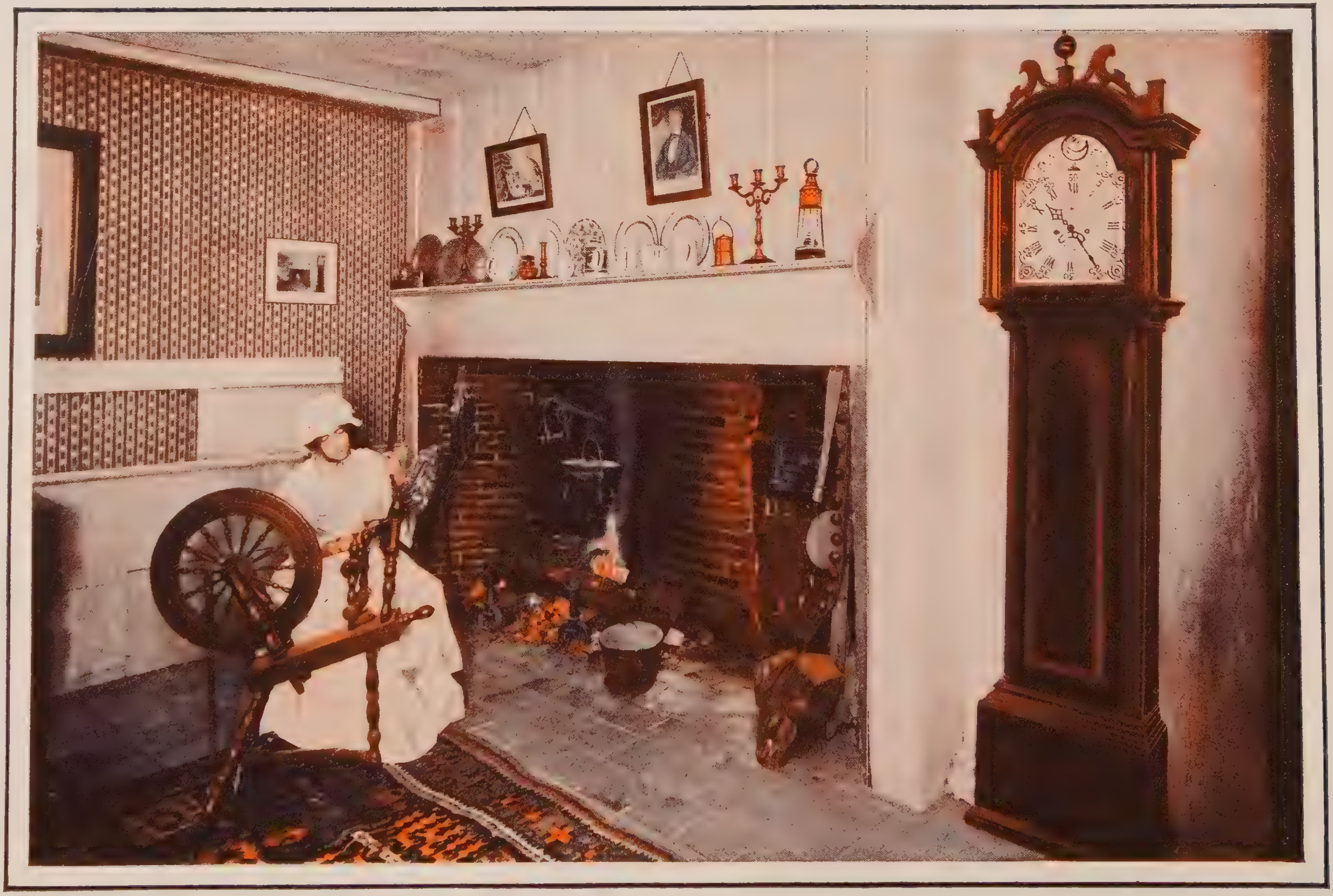

IN THE DAYS OF COLONIAL ARTS AND CRAFTS

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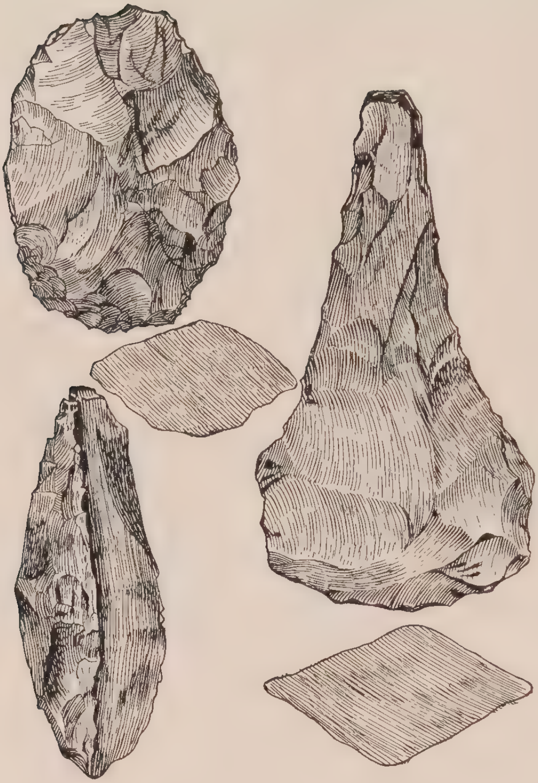
MAN'S EARLIEST INVENTIONS

THE first man was indeed a child of Nature. Naked upon the naked earth, he was fed and sheltered by it as if it were his mother. Yet Nature was his enemy as well as his friend. He must fight the wild beast, avoid the serpent, and watch for dangers on every side. The falling tree might crush him, the river drown him. Nature's forces would help him if he used them rightly, or would harm him if he did not; and like the wild beasts among which he lived, he must learn to avoid dangers or be destroyed. But man after a time began to do more than this. In simple ways he used his wits to make the forces of Nature aid him. In doing this he began to make tools — a trait which no other creature of earth has shown.

THE EARLIEST TOOLS OF MAN

When first a man picked up the broken limb of a tree and used it as a club, or threw a stone at a wild beast that threatened him, the age of invention had begun, a period that was to lift him far above the level of the beasts among which he had his origin. It is through the invention of tools and their use that man has grown from a child of Nature to the civilized adult of to-day with all his mighty force of intellect.

Man alone of all creatures thinks of things as tools and uses them as such. Through his inventive genius a stick became a club with which he defended himself from the wild beast and killed the venomous serpent. Soon he saw that if it was sharp he could thrust with it, and he had a spear. Then he threw it, point first, and had a javelin. Simple as this seems to us now, each step in advance was a tremendous one for primitive man; and when, perhaps ages later, some man found that he could bend another stick with a cord stretched from end to end and shoot the javelin from that, thus having a bow and arrow, how great a farther advance that was. But that could happen



TOOLS OF THE ROUGH STONE AGE
These implements, used by men of the Paleolithic Age, are told about more fully on page 290, Volume I.

only after men had made many other inventions, for to have a cord — even the sinew of a deer, a long strip of deer hide, or a cord of twisted strong grasses — meant other inventions to lead the way. Before a strip of rawhide or a sinew might be used, man must have had something that would do for a knife. So the beginning of all inventions, the very primitive sharp stick with which to jab an aggressive beast, or the stone to throw at him, led man on, step by step, to all the weapons and tools which have come after.

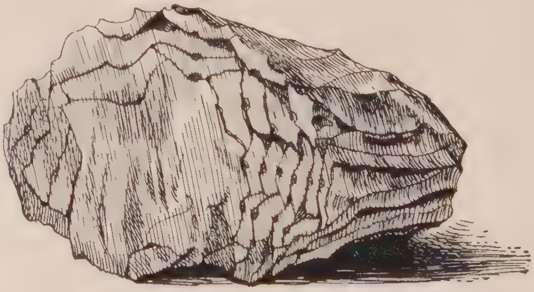
It is interesting to see how man took the things which he found at hand and turned them to his own uses. Primitive man could cross shallow rivers by wading, but some streams were too deep, too swift, or too wide for wading or swimming. Across a swift, narrow one, he might find a tree fallen and thus get the idea of a bridge. Across the wide, placid ones he could float on a fallen log and thus find his first boat supplied by nature. All bridges and all ships have grown from these simple beginnings. In the same way the stone, which was his first hammer, became when it had a sharp edge his first ax, and when it was both sharp and slim, a knife. From these two have come all the numberless kinds of cutting tools.

THE AGES OF STONE

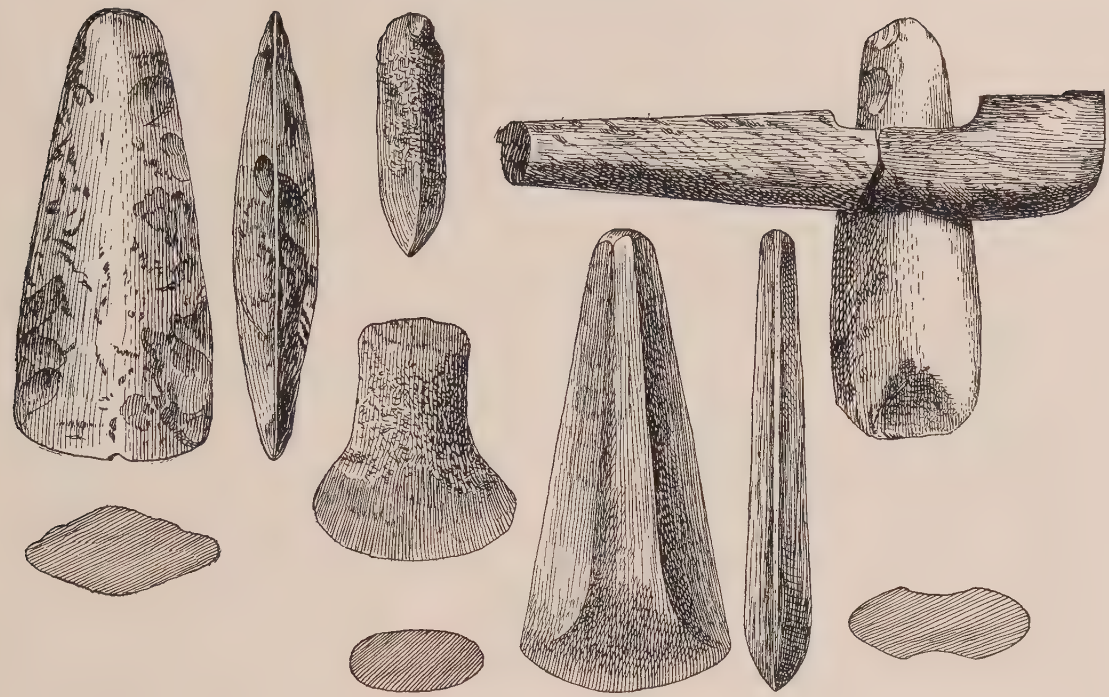
The first men of whom the earth has left us any record were those who used rough, chipped stones for weapons and tools. These stones are dug from the earth in many places and show that the men who used them lived in those localities. For many thousands of years men lived on with only these rough stones for axes and knives, for spear and arrow heads, and we call that age the Rough Stone Age. Then they began to polish the tools by rubbing them against other stones or with sand, and we have the Smooth Stone Age.

HOW DID THE STONE AGE MAN SHAPE HIS FIRST IMPLEMENTS?

Wherever primitive man has dwelt, we are quite sure to find tools of flint. For the Stone Age inventor discovered that this mineral breaks readily into flakes with sharp, smooth edges. It was not beyond his skill to secure flakes of good size and to shape them to his simple needs. A glance at the drawing at the foot of this page shows how he went to work. Many of the most beautiful flint tools that we find are those that were made by the North American Indian, for savage man has been much the same in all ages and lands. The workman takes advantage of the peculiar struc-



FLINT CORE WITH FLAKES REPLACED UPON IT



TOOLS OF THE SMOOTH STONE AGE

These are good specimens of the celts, as they are called (from the Latin *celtis*, "chisel"), implements in common use by men of the Neolithic Age. Their flat blades were designed for cutting timber, killing animals, and other purposes.

ture of the mineral, and his skill consists in adjusting the force of his blow to the size of the flake which he wishes to remove.

THE GREAT GIFT OF FIRE

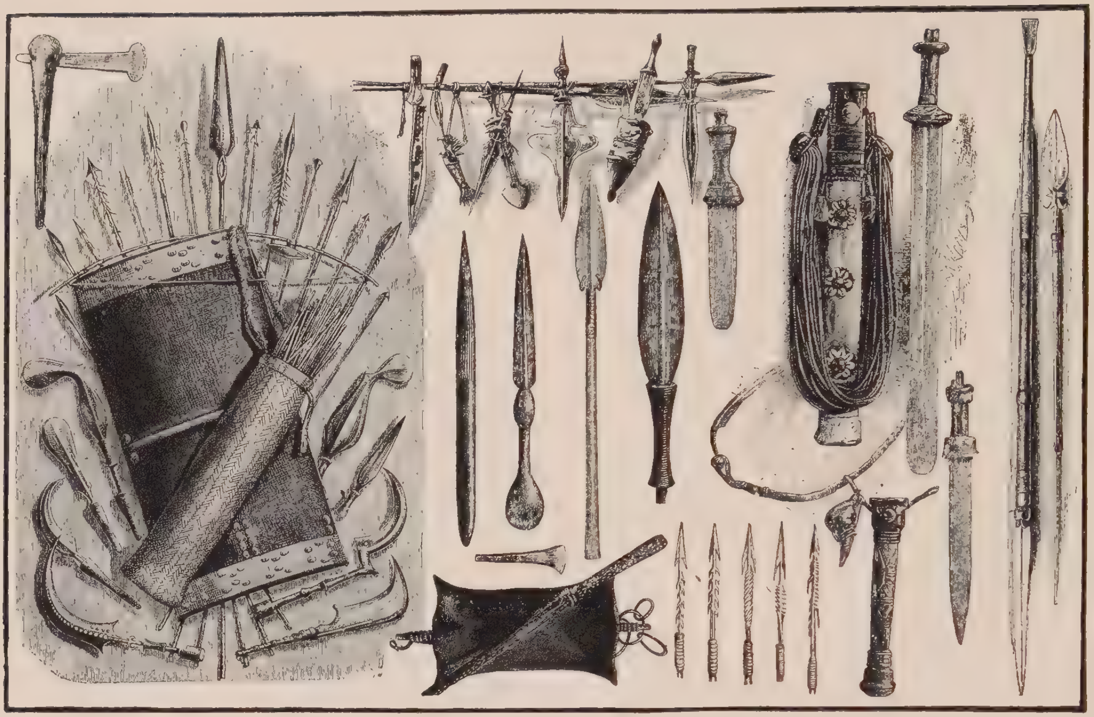
The ancient legends have it that fire first came to men from heaven as a gift of the gods. Fire was, indeed, a great gift to man, and no doubt it first came from heaven in the shape of lightning, which often sets fires to-day. Yet when lightning set fire to the forests and swept all before it in terrible death, it must have been a bold and inventive primitive man indeed who dared to try to use this scourge. The beasts to-day flee from fire and dread it, as they have always done. Man has learned to master it and make it tremendously useful to him. First he used it for warmth, then for cooking his food, and later, no one knows how many thousand years later, finding that heat would convert water into steam, began to use it to help him in his inventions.

THE BRONZE AGE

After this came the Age of Bronze. Man found that his servant, fire, would melt certain stones and leave behind a metal which could be shaped into far better tools than he had ever had before. This was a mixture of copper and tin, such as could be smelted from the ore with a moderate heat. The Bronze Age has left us many relics of the work of these early men who made not only tools and weapons, but household utensils of many kinds, and showed a great advance over the men of the Smooth Stone Age which preceded theirs.

THE "LOST ARTS"

To this period belong many of the so-called "lost arts," which we, with all our modern skill, have sought in vain to recover. Among these is the very important art of tempering bronze, which might be quite as useful to us as to the men of the Bronze Age. Another



WEAPONS OF THE IRON AGE FOUND AMONG VARIOUS PEOPLES

lost art is that of engraving on very hard gems. Our modern cameos are cut in shell, or onyx, but the ancients were able to carve exquisite designs on the hardest of precious stones. There are other lost arts which belong to the Bronze Age, or times but little later. Among these was an art of painting in wax so that the exposure of ages has scarcely dimmed the color of the paintings. In fact, men of the Bronze Age were very cunning workmen, and not inferior to us in skill of hand or artistic feeling. Homer's description of the bronze shield of Achilles is probably an invention of his own imagination; but just such beautiful work must have been familiar to the poet's audience, or they would not have believed his account.

THE IRON AGE

But man, continually advancing in inventive genius, found that iron, which may be made from the ore only by a far greater heat than bronze, could be melted out of his primitive furnaces and shaped into much harder and keener tools and weapons.

Thus came the Iron Age in which we live to-day, with all its wonders of inventive genius crowding one upon another so rapidly that day by day, almost, we are astounded at the progress made. Within little more than a century we have seen the vast development which has come from the application of steam as a motive power to machinery, and within half that time we have seen electrical inventions so increase as completely to overshadow the wonders of steam.

It is hard for us to understand how men lived without those things which we now enjoy; but to each generation its own time is the most wonderful of all. Indeed, many early inventions brought about greater changes than are ever likely to come from future discoveries. One of the epoch-making devices, for instance, was the alphabet, invented by the Phœnicians; but in this volume we are to tell only of mechanical inventions.

In Volume One you will find not only the story of prehistoric man, but also tales of Indians, Eskimos, and other primitive peoples who are now living or have within a century or two been living much as did our early ancestors.

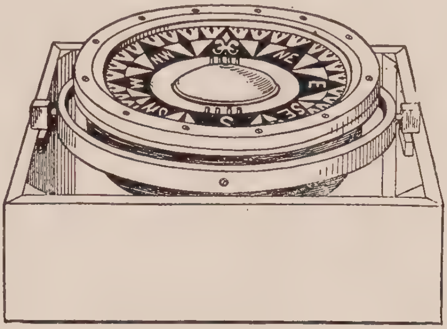
THE EDISON OF ANTIQUITY

The wizard of antiquity was Archimedes, a Greek who lived in Syracuse in the third century B.C. Archimedes invented so many things and was so far in advance of his age that some of his ideas seem almost modern. Most of his practical inventions of which we know were for use in the wars of the Syracusans. But perhaps the most important inventions of early times were those having to do with navigation — the anchor and the compass. The anchor is a simple device of metal so shaped that the pull of the cable by which it is attached to the ship tilts it upward and causes the flukes to be buried in the mud. Without this device navigation would have been confined to small boats, as in the days of the Homeric heroes, who drew their ships from the water each night.

THE MARINER'S COMPASS

It seems to be well proved throughout the history of mankind that it is a mechanism that makes an era. Among savages, for instance, those tribes who use the bow and arrow, though side by side with those who do not, in the jungle, are living in a later and more advanced age of the world. In ancient times the making of weapons and tools of iron lifted nations far above those who still used bronze, just as the invention of bronze had lifted others far above those who used stone only. So the mariner's compass ushered in a new era. It gave the sailor courage to sail forth on uncharted seas and opportunity to discover new lands, starting an era of exploration and colonization that will endure until the last corner of the remotest sea is charted, the last habitable land occupied by civilized colonists. With the use of the mariner's compass began modern times.

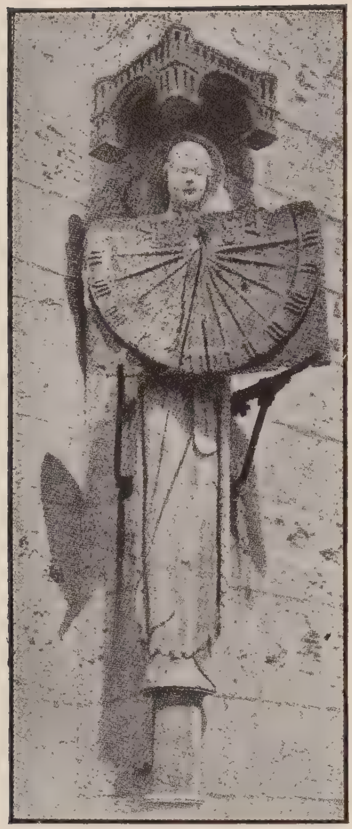
It has been known for ages that a magnetized substance, if suspended and allowed to turn freely horizontally, would point north and south. That is what the mariner's compass is, though as it is now used one does not think of it so much as a needle as a dial with many points. However, that is the principle on which the magnetic compass is built. Nor does the needle point to the true poles, but to the magnetic poles of the earth, which are situated at some distance from the true poles. Hence mariners using the compass must allow for its "variation," and thus find the true north by calculations based on experiment and observation in various parts of the world. In most portions of the seas usually sailed this variation is slight, but there are certain parts of the earth where it is very great. These regions are difficult of access, being in the far north, but it is possible to reach portions of the northern hemisphere where the magnetic needle points west instead of north. In other places, west of the magnetic pole, the compass points east; while if one were on a line between the true north pole and the north magnetic pole, he would find the compass pointing due south. However, the variations of the compass, great and small, have all been figured out and may be easily obtained by any navigator.



THE MARINER'S COMPASS

An interesting experiment, showing the principle on which the compass is founded, is to take a common needle, magnetize it by the use of a small magnet, stroking it the same way for a few times with the magnet, then oil it and float it gently on the surface of a vessel of water. The surface tension of the liquid will hold up the needle, if it be carefully placed there, and it will point to the magnetic pole.

A ship's compass rests in a stand called a "binnacle." It consists of two or more "needles" which are composed of thin layers of steel or bundles of steel wires, magnetized. These are fastened to the under side of a card on which the main points of the compass and thirty-two subdivisions are depicted. This card is delicately balanced and swings with



SUN CLOCK ON CHARTRES CATHEDRAL

the motion of the needles so that the point marked N points always to the magnetic north. The whole is inclosed in a brass case which again is suspended by two concentric brass rings so joined that, however the ship swings, rolls, or tosses, the compass card will always be level. The compass on a ship in motion is watched day and night by the helmsman, who sets his course by it.

HOW DID THE ANCIENTS MEASURE TIME?

The sundial was invented by Anaximander in the seventh century B. C. It answered every purpose for measuring time until the hourglass was devised, which was more accurate for the measurement of short periods, from three minutes to an hour. Clocks were invented sometime in the eleventh century. A clock made in 1348 was exhibited, going, at the Centennial Exhibition of 1876. These ancient clocks were in all respects similar to our own. They did not use a pendulum, which was not invented until several centuries later. Some attribute this device to Galileo, the great astronomer; others to a London clock maker named Harris. It is probable that Galileo first observed the regularity of the swing of the pendulum, and that Harris made the first practical pendulum clocks. The first clocks were tower clocks. One was placed in Westminster Abbey in 1288. Henry VIII gambled away its beautiful bells!

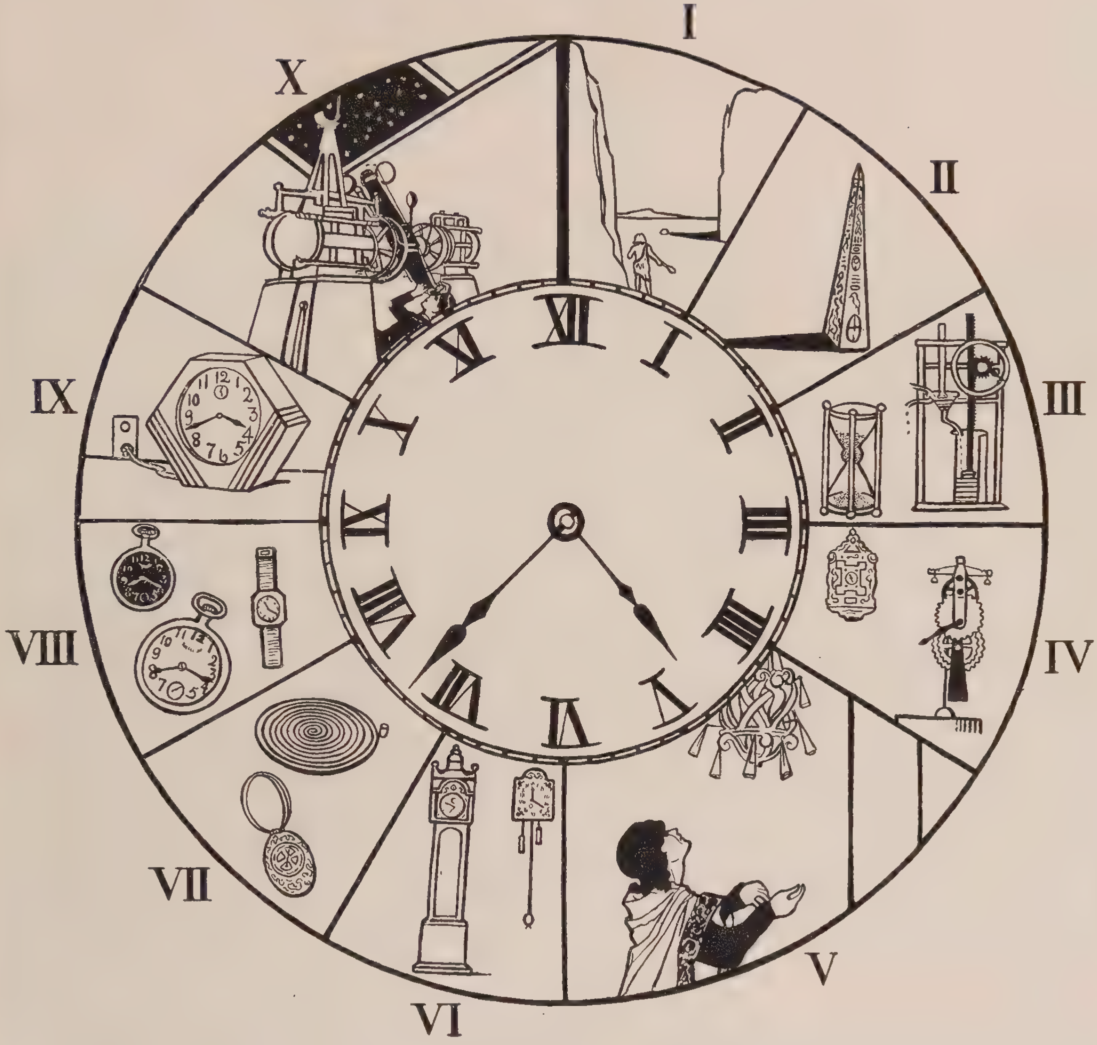
THE HISTORY-MAKING INVENTION OF GUNPOWDER

Gunpowder was invented by the Chinese, we do not know just when. They, however, made no important use of their discovery. But when it was rediscovered by Schwartz in 1320, it changed the course of history. Until then one man-at-arms in full armor was superior to a whole troop of rudely armed peasants. As only the rich could buy armor, the power of the great over the masses was irresistible. But gunpowder changed all that. Armed with his gun, one man became as formidable as another. The invention of cannon preceded that of handguns. The first guns were so heavy and clumsy that they were almost as dangerous to the shooter as to his enemy. By the beginning of the eighteenth century the gun had become an efficient weapon. Armies were reorganized and the era of modern political history began. The great military genius of this period was Frederick the Great of Prussia. It was he who adapted army organization to the use of firearms.

Gunpowder was known to the nations of the Far East,

A COLONIAL CLOCK

TIME TELLING DOWN THE AGES



A PICTURE STORY OF MAN'S INVENTIONS FROM SUNDIAL TO CLOCK

I. Cave man telling time by the shadow of a cliff.

II. The shadow of an Egyptian obelisk serves as a sundial.

III. In the hourglass and the water clock, man invents his first time machines. Now he can say "how long" as well as "when" in his time telling; now he can tell time on rainy days and after dark.

IV. The balance wheel in the DeVick clock regulates the rate of movement. In 1364 DeVick of Württemberg was sent for by Charles V of France to build a clock for the tower of the royal palace. This clock, finished in 1379, was still running in 1750. It gave the signal for the Massacre of St. Bartholomew.

V. Galileo, a youth of seventeen, is standing in the cathedral at Pisa, timing the swing of a lamp suspended by a long chain with the beat of his pulse. The pendulum when introduced in clocks gave a mechanism which would move at a steady rate.

VI. Dutch Pendulum Clocks. Christian Huygens, the astronomer, was one of the first clockmakers.

VII. In the Nuremberg Egg Peter Henlein, about 1500 to 1511, used for motive power a coiled mainspring, which could be "wound up" with a ratchet.

VIII. Modern watches, one with the hands treated with radium so that they shine in the dark.

IX. The electric clock, in which the electric current serves as the motive power.

X. The observer at the United States Naval Observatory checking time by the stars. The cave man kept time by the sun; we of the twentieth century check our time daily by the stars.

to China and India, at a very remote period in history. In a crude way these nations applied it to firearms, though the results were more likely to frighten than harm the enemy against which the weapons were directed. The "Greek fire" of the Byzantine emperors and the "terrestrial thunder" of the Chinese may well have driven hordes of barbarians before them in fear of the flashing flames and the astounding noises, even if they did them no bodily harm.

The composition of this gunpowder used by the Chinese long before the Christian era does not materially differ from that of the gunpowder of to-day. Roughly it consists of three quarters potassium nitrate and one quarter divided between charcoal and sulphur. The burning of one volume of this powder produces 296 volumes of mixed carbon dioxide and nitrogen which, expanded by the intense heat of the explosion, are further increased to fifteen hundred times the volume of the powder burnt. This expansion it is which forces the projectile through the tube of the gun or rifle and sends it on its way with such force. But the amount of force depends on the rapidity with which the powder burns, and it was not until Bertholdus Schwartz in 1320 taught the nations to compress the powder and then granulate it that firearms became effective. Immediately after this discovery cannon appeared in the armory of almost every state, as if their use had been known previously, but they had not been considered practical because of the bad quality of the powder manufactured.

MUZZLE-LOADING CANNON OF PERIOD OF MEXICAN WAR

Now at Charlestown Navy Yard.

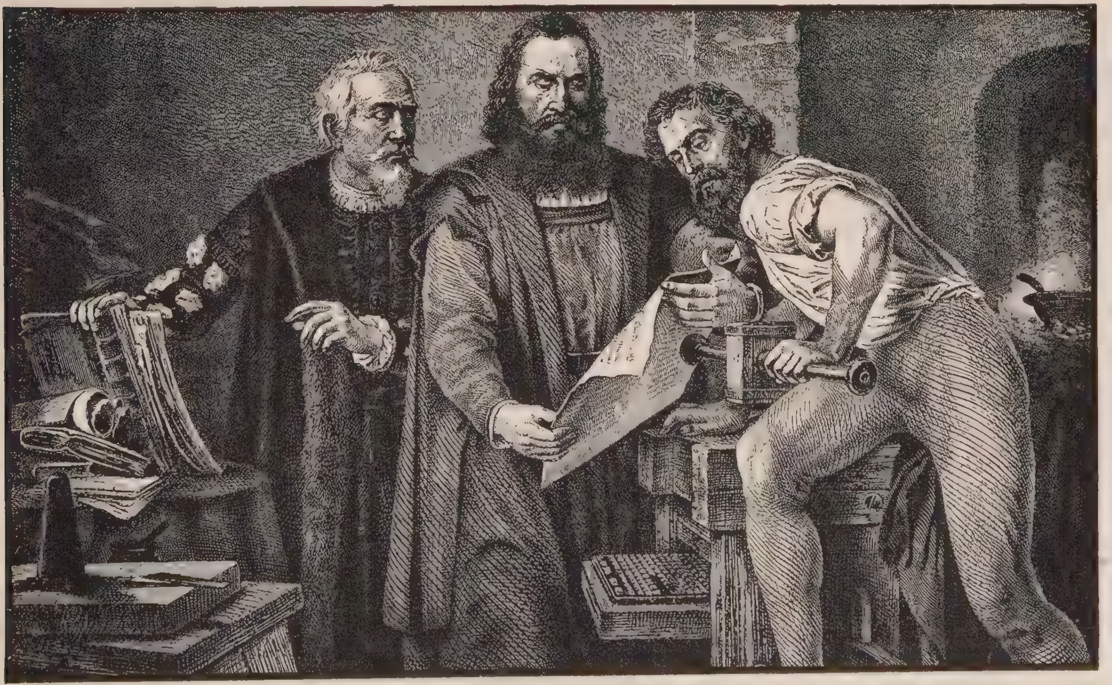
Like many inventions which have revolutionized the progress of the world, Schwartz's seems a simple matter; yet in the end it made a tremendous force, which had been known as a possibility for perhaps a thousand years, directly available as a servant of mankind. The use of gunpowder as an explosive in blasting and in other ways having no connection with firearms or war led directly to the invention of other stronger explosives, notably dynamite, which is a wonderfully effective agency in the work of the world to-day.

THE ORIGIN OF PRINTING

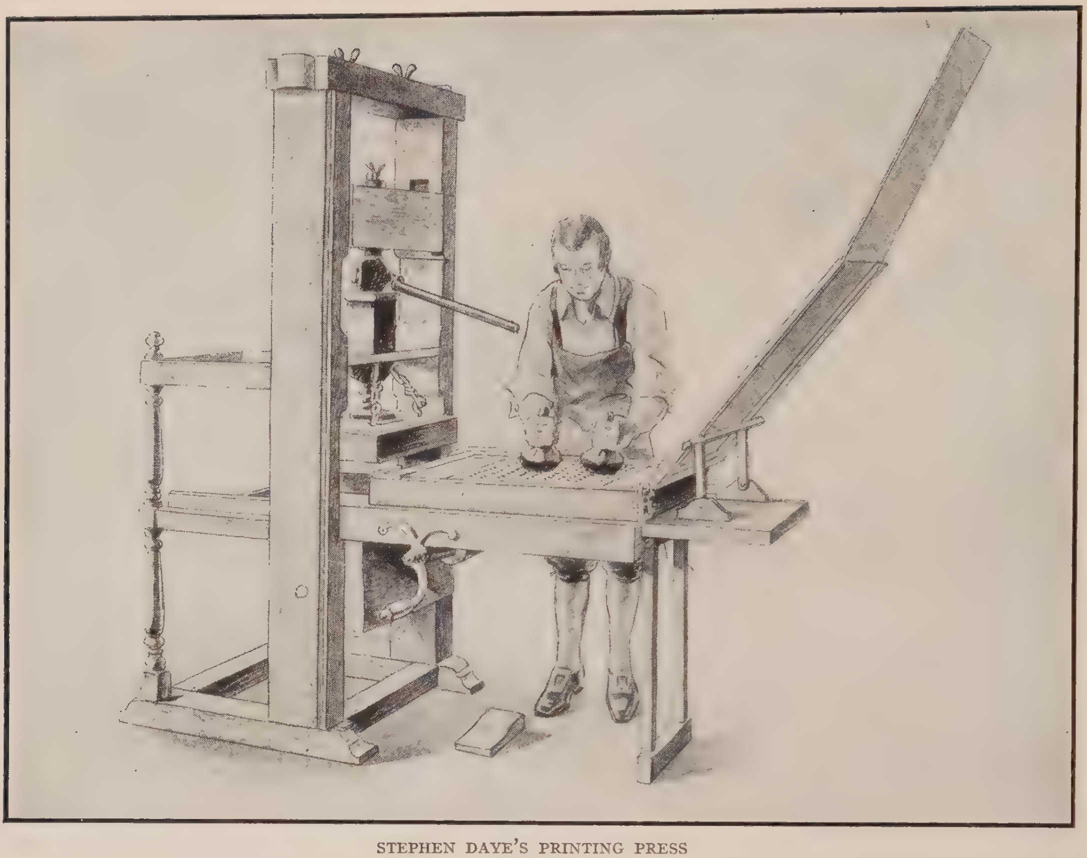
The art of printing dates back only a few centuries, although a kind of printing from solid blocks, instead of movable types, has been in use among the Chinese from very ancient times. Printing from movable type is said by the Dutch to have been invented by Lourens Coster in 1420, but the Germans claim that it was invented by Johann Gämsfleisch, of the Gutenberg family, in 1438. The inventor is known generally by the name Gutenberg. Within twenty-five years the invention was known and practiced in the leading cities of Europe. William Caxton introduced printing into England, setting up a press in Westminster Abbey.

For more than two centuries little or no progress was made in the method of printing, although many famous printers flourished during that time. The most noted were Aldus, in Italy, and Elzevir, in Holland. The work of these and other early printers is often very beautiful and exact, and is seldom equaled in the printing of our own time. The reasons for this are, first, that the work was all hand work, slowly and carefully done; secondly, the paper used was a beautiful handmade linen paper which would be too costly for use to-day; and, in the third place, the printers made their own type, and but few impressions were taken from the same type. But the real superiority of early printing came from the fact that the printers were themselves leading scholars, and took an intense interest in the accuracy and beauty of their work. The pioneer printer of the United States was Benjamin Franklin. He invented a hand press which, with very little modification, is still used in most printing offices for taking first proofs from plates and type. The first printing press in British North America was brought from England in 1638, by Stephen Daye.

The first centers of printing were Antwerp, Leyden, Paris, and Venice. In these cities originated most of the early types. The style known as "italic" is said to have been a copy of the handwriting of Petrarch. Most of the types used in England came from Holland. The great University Press of Oxford, England, still casts type from a set of molds imported



THE FIRST PROOF FROM GUTENBERG'S PRESS



STEPHEN DAYE'S PRINTING PRESS

The first press in British North America, brought from England in 1638. Now in the State House at Montpelier, Vt.

from Holland. This type is reserved for their best publications and is of great beauty. The molds are of brass into which the form of the letter has been struck by a steel die. This gives a very sharp, clean edge to the letter. The metal ordinarily used is an alloy of tin, and antimony with lead. The early printers applied the ink to the type with a brush, as you would blacken a stove. The paper was dampened and laid on the type by hand. The pressure was applied by a screw or lever. Slow as this laborious process was, how marvelously rapid it must have seemed to those who had been accustomed to books lettered with a pen by hand!

HAND SPINNING AND WEAVING

Little more than a century ago every girl was taught the graceful art of spinning, and she learned, too, to weave; for on her skill at these arts would depend the clothing of her household after she married. It seems hard to believe this nowadays, when great factories turn out enormous quantities of beautiful fabrics daily and the art of spinning and weaving by hand is almost entirely a forgotten one. Yet from the most distant times, until modern invention changed it all, spinning and weaving were household occupations. In ancient mythology the three Fates — Clotho, Lachesis, and Atropos — were represented as spinners, the one holding the distaff, another twisting the thread, while the third cut it off when life was finished. On the earliest Egyptian monuments we have representations of the spindle and distaff — primitive spinning tools as compared with which even the spinning wheel of our grandmothers was a great improvement. The distaff, on which was placed in a fluffy mass the material to be used, was held in one hand while the spindle was whirled in the other with a bit of the fluff attached and gradually drawn away. This made the thread. In the spinning wheel the spindle was set in a frame which was made to revolve rapidly by a big wheel and a crank operated by a treadle. With this the spinner used both feet and hands and, becoming expert with long practice, was able to spin a much larger amount of thread in a day. As late as the beginning of the last century a modification of such a spinning wheel was in use in many countries.

But we must not think that our forefathers were interested only in war or the absolute necessities of life. Many beautiful works of art were wrought on the old hand looms. Indeed, in that way the most artistic work must still be done, and there is a revival of the use of the hand loom in our own day for the making of fine curtains, table linens, and tapestries. The most wonderful hand weaving is that done at the Gobelin Tapestry Works in Paris. This establishment was founded in the fifteenth century, and the same methods are still employed. Since the days of Louis XIV the Gobelin Works have been the property of the French government.

FORERUNNERS OF THE PIANO

The invention of the clavier, or keyboard, was the real beginning of the piano, although its first application was to the organ. Then came the clavichord, an instrument of stretched wires played by a keyboard, the first mention of which dates back to 1404. This was followed many years later by the harpsichord, so called from the shape of the sounding board, which was that of the harp, like a modern grand piano. A third instrument of the same class was the virginal. Upon these instruments some of the greatest of our classical music was com-

Distaff Spinning.

From "The Story of Textiles"

FLAX SPINNING IN EARLY NEW ENGLAND DAYS

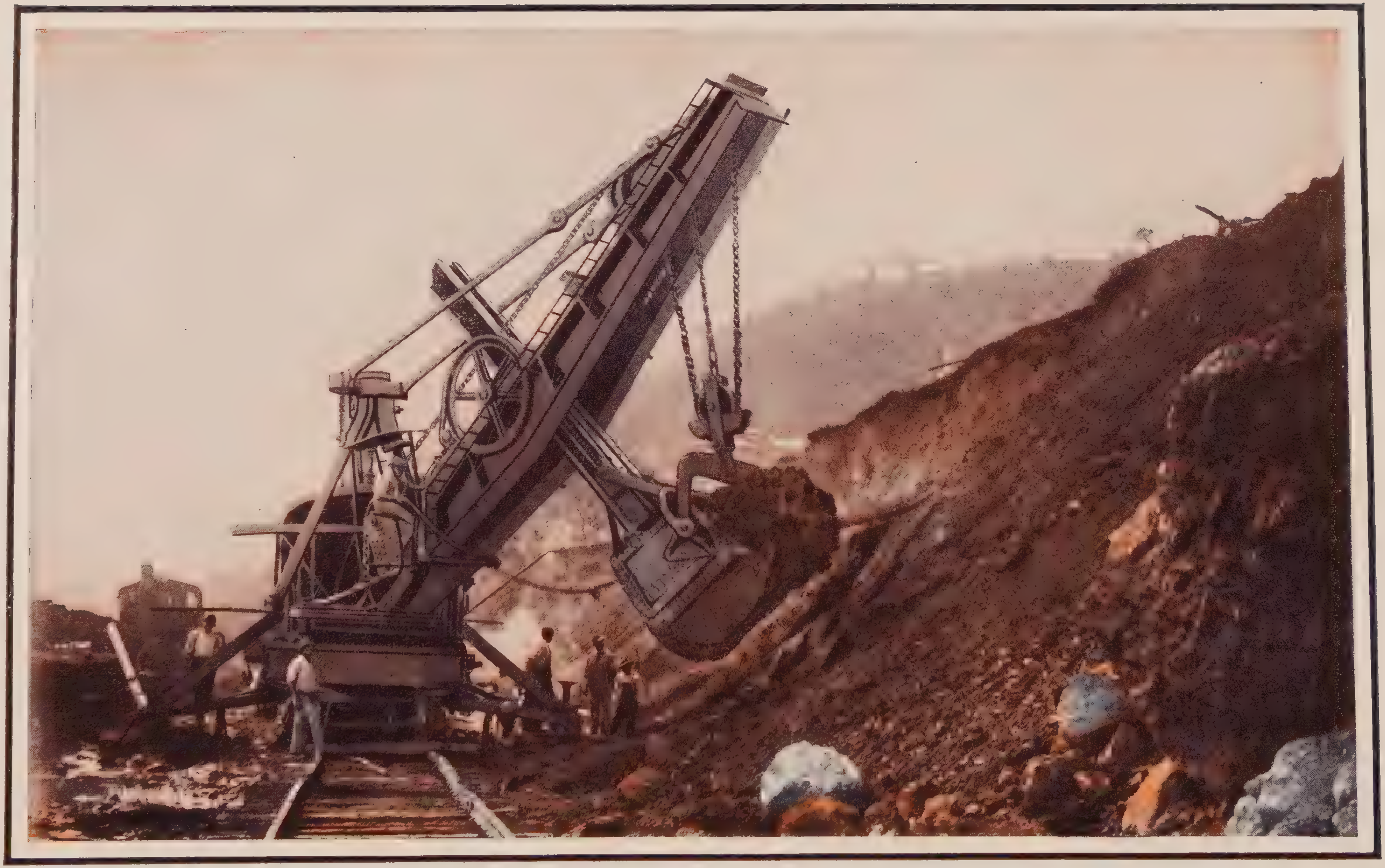
posed, such as the great works of Sebastian Bach and not a little of the music of Mozart. Queen Elizabeth was a fine performer on the virginal, and its use became a fashionable accomplishment. Haydn and Beethoven were very partial to the clavichord. The spinet, of which you will often hear, was a small form of the harpsichord. These inventions all belong to the seventeenth century and reached their highest perfection about 1700. Clavichords are now made in small numbers for special purposes. The piano was invented by an Italian named Bartolomeo Cristofori, about the year 1720. He was a harpsichord manufacturer, and his improvement was so revolutionary that it was long before it was received with favor by musicians. The reason for this was, not that it was not an obvious improvement, but that it necessitated learning to play all over again, and this they were not willing to do for the sake of helping a new invention. Nevertheless, the change was certain to come. Those who resist progress never succeed for long.

The essential difference between the pianoforte (as it was called, because it could be played "softly" or "loudly") and the instruments of the harpsichord type was that in all the earlier instruments the wires were picked, mechanically, and in the piano they were struck with a hammer. The improvement enabled the player to produce a far more powerful, rich, and varied tone, and at once lifted the instrument into a new rank. Pictures of these early instruments are shown in "The Story of Music" in Volume Five on pages 250–254, where their full story is told. We mention them here because of their importance in the history of inventions.

TWO EARLY SCIENTISTS, FRANKLIN AND RUMFORD

Two names, both associated with colonial America, link the ancient with the modern ages of invention. Of Benjamin Franklin we have already spoken, as one of the pioneers of the printing press, and we shall have occasion to speak of him again, in telling about electrical inventions. He combined the interest of the scientist with the practical skill of the inventor, and was thus able to make many contributions to the comfort as well as the progress of his generation. But we may well give place here to a few words concerning Count Rumford. His real name was Benjamin Thompson, and he was born in Woburn, Mass., in 1753. In the War of the Revolution he adhered to the English cause, and removed to England. His great mechanical genius and scientific attainments soon brought him substantial position, and he died wealthy, and honored by the title by which he is now known. He showed his affection for America by establishing the American Academy of Arts and Sciences, an institution that has done much for American science. Rumford's most practical invention was that of the stove. He observed the great waste of fuel in open-hearth combustion, and devised an enclosed stove with flues and drafts. This invention revolutionized domestic economy.

The invention of the cotton gin and weaving loom forms a transition to the age of machinery.



A STEAM SHOVEL SCOOPING UP A CARLOAD OF GRAVEL AT ONE BITE

USES OF THE LEVER

Left: as primitive man might have used it. Center (above): the Egyptian *shadoof*, for raising water; (below): the American well sweep. Right: the steam shovel.

THE AGE OF MACHINERY

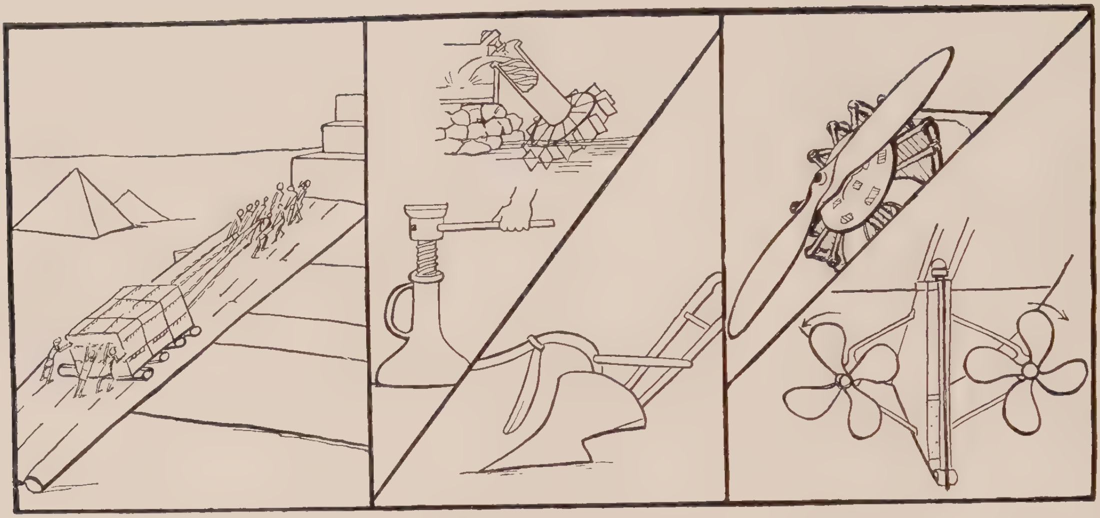
A CALENDAR of patents for the nineteenth century shows from one to ten important inventions for each of the one hundred years. It is as if we had been for a long, long time drifting in a stream so quiet that not a ripple broke its surface, when we suddenly felt the pull of a powerful current, a forward lurch and motion ever swifter and swifter. We have reached the Age of Machinery. Invention follows invention with bewildering rapidity. We must select; we cannot describe, we cannot even mention, all. What wonder is it, after such a revolution in man's way of doing things, that there is great restlessness, that relations between the employer and his employees are frequently strained, and that many readjustments are required!

HOW DOES A MACHINE DIFFER FROM A TOOL?

We call anything a tool which requires both the strength and skill of man for every motion performed with it. The moment an automatic feature is introduced into any device, however slight it may be, and a portion of the work is done by its own adjustments, we have a machine. A fork in the hands of a cook beating an egg is a tool, but a simple Dover egg beater is a machine. It transforms energy into a new direction and of itself supplies the adjustments necessary to do this. The most significant feature of such an article is that it reduces labor. Hence we have the popular, and not inaccurate, definition of a machine as a labor-saving device.

WHAT MAKES THE MACHINE GO?

The first principles of mechanical inventions were discovered by the men of very early times, of which we have no record other than the stone implements which they left behind. These principles were the first uses of the lever, the inclined plane, and friction. On these for a foundation have been built all the intricate inventions of our own day. No one knows the names of these first inventors; indeed, it is probable that many men, in various climes and in centuries wide apart, found out, each for himself, these principles and the application of them. Something like that is true even of our modern inventions. A hundred minds in different countries work upon the same problem, such as the invention of a telephone or an airship, and the solution seems to come to many of them at about the same time.



USES OF THE INCLINED PLANE

Left: building the pyramids. Center (above): the Archimedean screw for raising water, and the jackscrew for lifting heavy weights; (below): the plow. Right (above): the airplane propeller; (below): steamship propellers.

THE LEVER

No doubt many a small boy to-day learns through his own experience and experiments that the lever may be used in many ways, just as some primitive ancestor did, without making a particular study of the reasons why. Yet such a particular study was made more than two thousand years ago by the famous Syracusan, Archimedes, whose remark, "Give me but a fulcrum [place] to rest my lever upon and I could move the world," has been repeated millions of times by those who had slight idea of the laws of the lever or the meaning of the statement. The action of the lever may be illustrated by a pair of scissors, a wheelbarrow, or a pair of tongs, but there is only one law — that a large weight may be moved through a small distance by a small weight moving through a proportionally greater distance. For example, if one arm of the lever is ten times as long as the other, the power of one pound will lift a ten-pound weight. By the same principle, if you could make a lever the long arm of which should be millions enough of miles in length, one man could exert force enough to balance the earth, just as Archimedes said.

It is a not uncommon sight to see men hoisting a safe to an upper window in one of our city blocks. Watch them and you will see a modified form of lever. One or two men will wind a windlass, and the safe will rise slowly in the air. The men themselves could not for a moment lift it, but they can hoist it with the help of the pulley. Archimedes knew all about this, and was regarded as something more than human because he set up a system of pulleys that made it possible for him, sitting on the shore, to draw a heavy galley from the water. A windlass is a cylinder turning on an axle propelled by a long handle, a rope being wound about the cylinder. The axle is the fulcrum; the pull on the rope, the weight. The same law of the lever acts in the case of toothed or cogged wheels, or wheels of different sizes placed at a distance apart and connected by a belt, which may also lengthen the lever arm. It is wonderful in what a variety of ways this principle of power can be applied. The modern derrick or crane is a fine illustration that may be seen where any large building is in course of construction. In the excavation work on the Panama Canal the steel steam scoops were among the wonders of mechanism, moving as though animated with a human intelligence, but with more than human precision and power. Take the first chance you can get to watch a steam scoop or a steam dredge in the river or harbor; and then remember that this massive machine, with its steel beams and chains and great scoop with hinged bottom, works on the same simple principles of the lever that Archimedes discovered.

THE INCLINED PLANE

Suppose it is necessary for one man to raise a barrel of sugar weighing three hundred pounds through a distance of four feet. It is practically impossible for him to do this work by main strength, but by arranging a plank twelve or fifteen feet long, so that one end rests against the upper level and the other against the lower level, the barrel may be rolled up this inclined plane with very little difficulty.

The ax is probably the oldest example of the inclined plane, though combined with a cutting edge. It is found in the Rough Stone Age and in all ages since, from the earliest stone ax to the latest blade of tempered steel and well-balanced handle. Here is applied the principle of the wedge. The principle is of very ancient use, and was employed in building the great pyramids of Egypt. In modern machinery it is most used in the wedge and the screw, the latter being simply an inclined plane adjusted spirally about a cylinder. You may not have thought of a knife blade as a very thin wedge, but so it is, and every time you cut with one you are using the principle of the inclined plane, just as you are when you use a hatchet or an ax, namely, of spreading apart two surfaces by driving between them a piece of wood or metal shaped with sloping sides. When wood is split with an ax, or sharpened wedge, the fibers are forced to leave their original position and slope at the same angle

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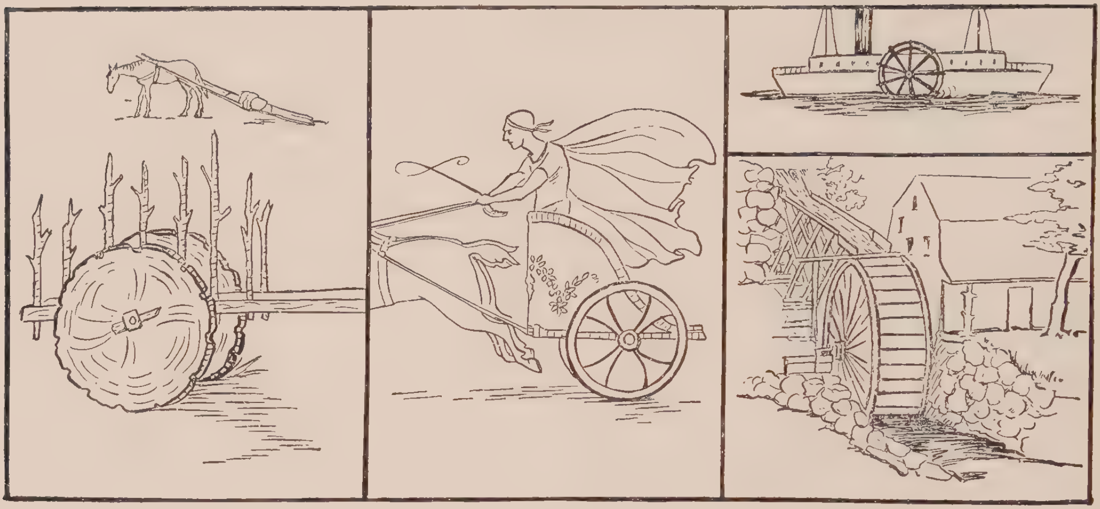
STEAM SHOVELS

These shovels or "scoops" offer good illustrations of the principle of the lever.



USES OF THE WHEEL

Left: a section of log used as a wheel to reduce friction from dragging heavy loads. Center: a Roman chariot. Right (above): the paddle wheel on an early steamboat; (below): the water wheel for producing power.

as that of the slanting surface of the wedge. Direct pressure downward, without the slant, would not have the same effect. By the use of the sloping surface, or inclined plane, the splitting of the wood is done more quickly and with less output of energy.

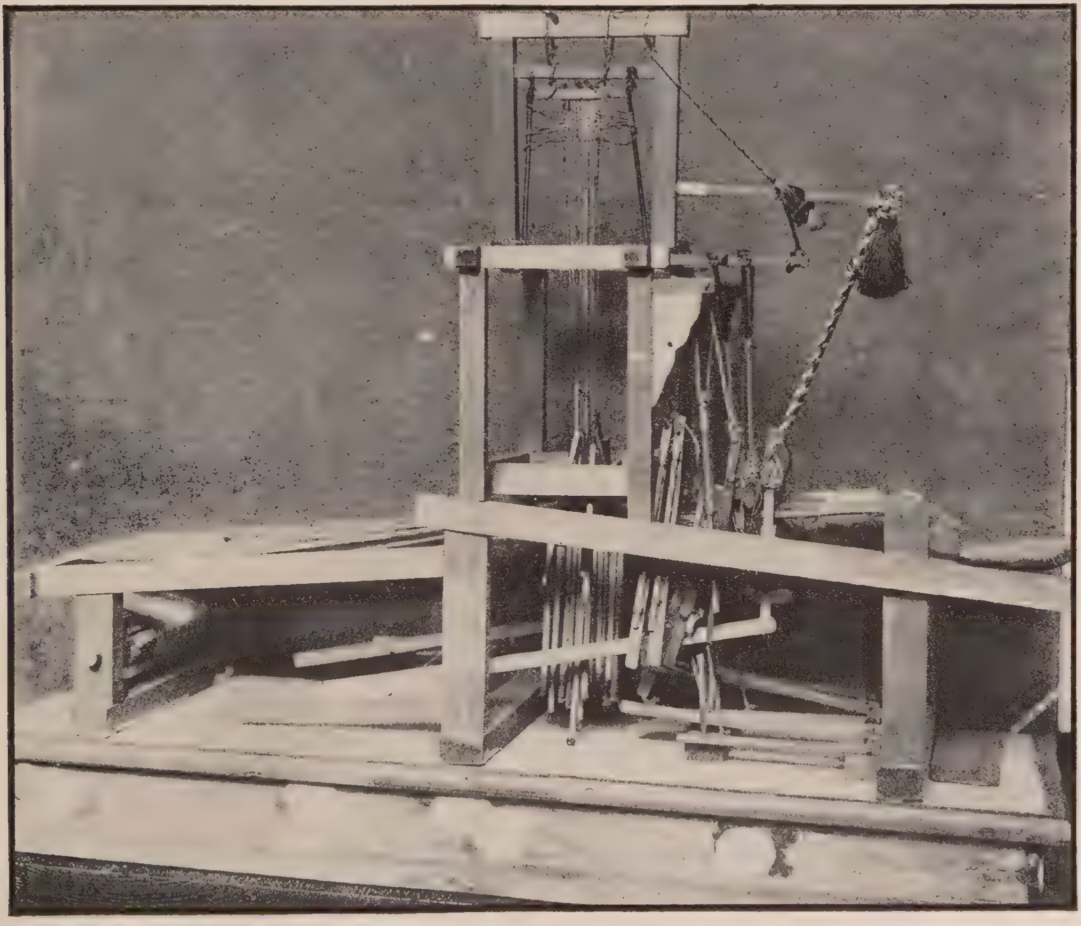
FRICTION

The third principle, friction, or the rubbing of one surface upon another, means loss of power, and gives the inventor trouble when he is trying to invent a powerful and smooth-running machine. Yet without it machinery would be useless. It is friction that makes the belt turn the wheel, that makes the car wheel move on the track, that makes movement of any kind possible. Friction is due to the fact that all surfaces, no matter how smooth they look or how carefully polished they are, contain roughnesses or granulations which often can only be seen under the microscope. If this were not true of all materials with which we have to deal, we could not walk or hold anything in our hands. This world would be too slippery a place for us. Friction is necessary, and the thing is not to have too much of it either in machinery or society. Friction depends upon the actual contact or rubbing of the roughened surfaces upon each other. It is much greater where the two substances slide over each other than where one rolls upon the other. The wheel is the primitive reducer of friction, and is in constant use to lessen loss of power. The best man could do before he discovered the use of the wheel turning on a hub was to carry his heavy loads on his shoulders or drag them along the ground on a pair of poles or runners. But the wheel vastly reduces the friction between a weight and the earth and makes it possible for a man to draw a load far beyond his power to drag or carry.

In modern machinery, power losses through friction are further reduced by the use of ball or roller bearings. Here again we find an application of the "wheel" idea, small balls or rollers of steel being introduced to prevent the rubbing of one metal surface on another. Friction, one of the principles which have made machinery possible, is also, strangely enough, machinery's greatest enemy. It not only wastes power, but will destroy the machines themselves if its effects are not guarded against. That is why so much care is given to lubrication, which is merely a means of reducing friction by the use of oil or grease on moving parts. The wheelbarrow, the lawn mower, or the wheels of wagons squeak and complain if not properly greased or oiled. If these slow-moving mechanisms show such evident effects of friction, it is far more important that gasoline engines and other high-speed machines have proper provision made for ample and effective lubrication.

THE INTRODUCTION OF MACHINERY

In 1764 Hargreaves, an Englishman, invented the spinning jenny, by which at first eight threads were spun at once, but this number was rapidly increased until the then surprising number of eighty were operated at one time. The spinning jenny did wonderful work in its day, but the woolen yarn and flax thread thus spun of old were coarse and uneven of texture. Originally wool and flax were carded; that is, combed by hand so that the fibers might be loose and lie parallel. But soon a carding machine was invented by which the wool, flax, or cotton fiber passed over toothed rollers which did the same work far more rapidly and evenly, gathering the fibers together into a loose, untwisted column called a "sliver." The operator then drew out the sliver into a thinner form having a slight twist, called a "roving," and this went to the spinning jenny. But a better way of treating the wool and flax was invented by Arkwright soon after the spinning jenny came into use, by which the rovings were drawn through rollers, one pair after another, and the thread made much firmer and finer. Again this machine, which was called a "throstle," was improved by the "mule



AN OLD HAND LOOM

From a model in the Peabody Museum, Salem, Mass.

jenny," which has a traveling frame in which spindles are set. This frame draws out and twists the thread as it leaves the rollers of the throstle, then moves back again, winding up the thread on the spindles as it moves, then goes through the first operation again. Crompton invented the mule jenny, and, by means of it, for the first time thread of great fineness was made.

From "The Story of Textiles"

Sir Richard Arkwright was the inventor of the roller spinner or water frame and founder of the first cotton mill in the world, at Nottingham, England.

Modern machines combine the operations of carding, roving, and spinning, and so well do they work that yarn has been made for the purpose of testing machinery, of such slenderness that a pound of it would reach 4770 miles. Thus the spinning, which during all earlier ages of the world was done by the women of the household sitting by the fireside, became a factory operation in which thousands of operatives stand side by side watching the machines, but taking no part in the work other than to mend a broken thread or supply fresh material for the whirling wheels.

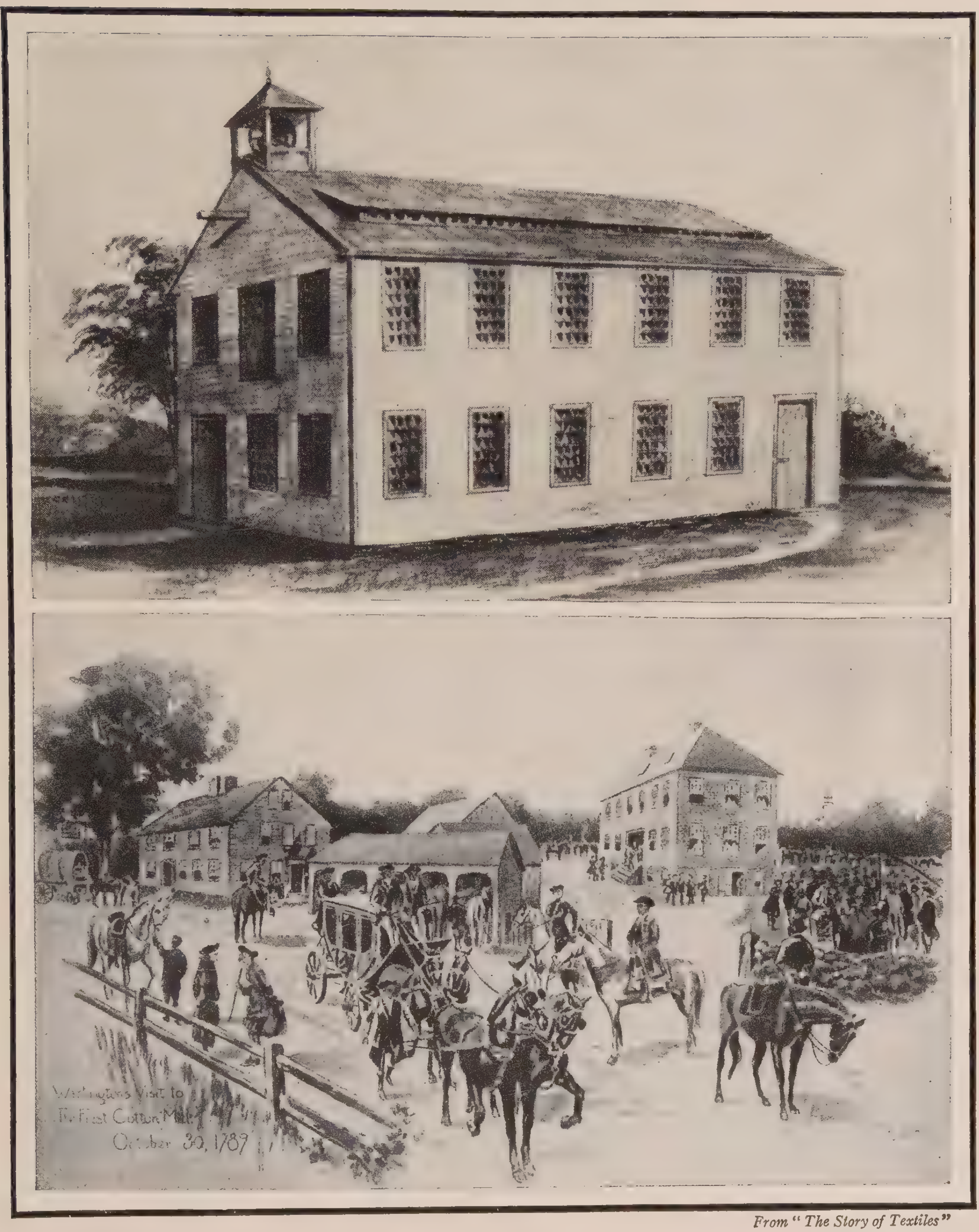
THE EVOLUTION OF THE LOOM

Weaving is perhaps the most ancient form of manufacture. In its simplest form it consists of interlacing threads or yarns to make a fabric. The most primitive people weave rushes in this fashion into mats, and even tribes otherwise considered savage weave coarse blankets in primitive fashion. The loom itself was an invention of the very earliest civilization. In Greek mythology, Minerva, goddess of wisdom, was famed for her skill in weaving. The story goes that Arachne, a Greek maiden, who was also skilled in weaving and embroidery, dared contest with her. Minerva admired Arachne's work, but was offended at the impiety of the subjects of her embroidery. So she changed the Greek maiden into a spider, and in this form, wrinkled and ugly because of the displeasure of the goddess, she yet continues to do most wonderful weaving.

Thus, so long ago were there hand looms that no one knows who invented them. They continued to be used through the ages, but little modified in form, until in 1787 one Dr. Cartwright, without ever having seen a loom before, constructed one to work by machine power. In its simplest form the loom is still worked by hand in many countries, and wonderful fabrics, such as Indian shawls, Turkish rugs, and the like, are produced that rival the most intricate work of the power loom. But for all that, the bulk of the world's weaving is now done by power.

HOW THE LOOM WORKS

In a hand loom parallel threads are stretched from a roller which is called the "beam," or "yarn roll," to another which is called the "cloth beam." The threads thus stretched are called the "warp." An arrangement lifts alternate threads near the cloth beam and holds the upper and lower threads separate while the shuttle, containing a thread of the



From "The Story of Textiles"

TOP: THE OLD SLATER MILL, PAWTUCKET, R. I., BUILT IN 1793. HERE THE FIRST COTTON SPINNING BY ARKWRIGHT MACHINES WAS DONE IN AMERICA. BOTTOM: WASHINGTON'S VISIT TO THE FIRST COTTON MILL AT BEVERLY, MASS., OCTOBER 30, 1789.

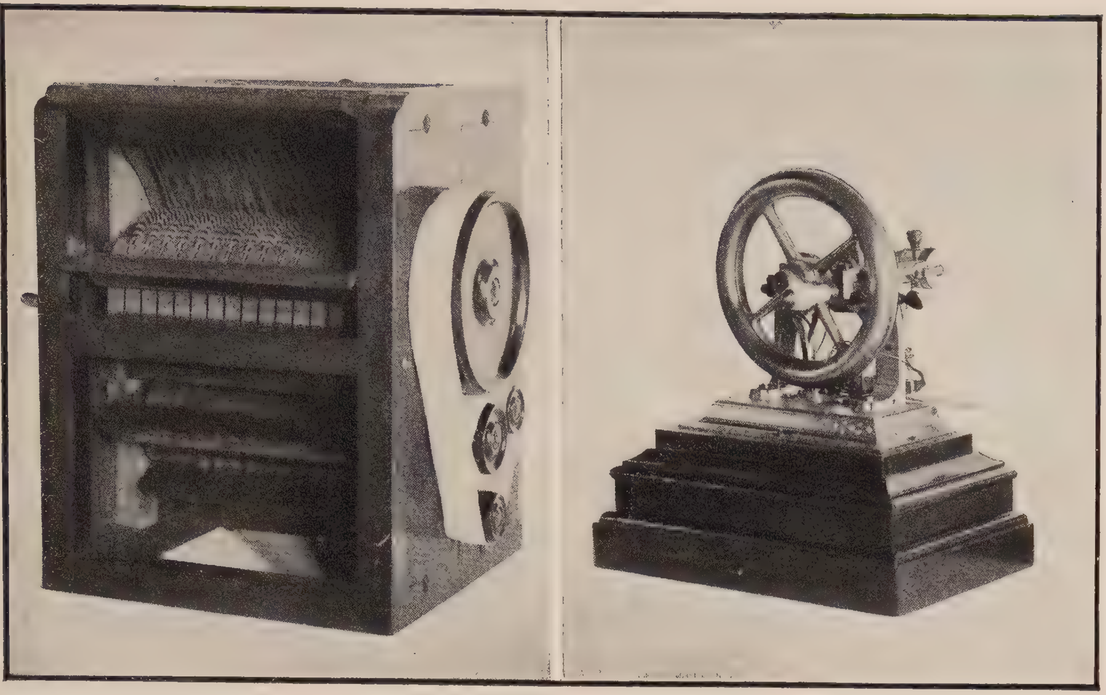
weft, is thrown through. This space through which the shuttle is thrown is called the "shed." Then the mechanical arrangement lowers the upper threads and brings those below up into their place. The shuttle then shoots back and carries the thread through the shed again, and the reeds, wires which go up and down through the warp, press the woven threads tightly together. The reeds and the shuttle are moved by the weaver's hands, the warp threads are shifted up and down by moving the feet. Thus the weaver sits at the loom, tossing the shuttle, kicking the treadle, and watching the fabric grow before his eyes. As the work progresses the warp unwinds from the warp beam and the cloth winds up on the cloth beam. Such is the work of the primitive hand loom which has been in use since long before the dawn of history. Its principles are exactly those of the latest and most complicated machinery, though they have been modified and improved by a thousand modern inventions.

Arkwright's first mill at Nottingham, England, was driven by horses, but this species of motive power was soon found to be too expensive. In 1790 he entered into a partnership with Mr. Jedediah Strutt, and they erected a mill at Cromford, on the Derwent, and operated it by water power. This was the first cotton mill in the world to be driven by a water wheel, and from this circumstance the spinning machines were called "water frames." The yarn made in this mill, which was, indeed, the first wholly successful one, was very much more even, firm, and hard than that previously made by the spinning jenny. In 1793 the firm began to make calico wholly of cotton, and this was the first cloth manufactured in England entirely of this material, linen always having previously been used for the warp. In spite of much litigation and jealous opposition and usurpation of his rights, Arkwright's success was wonderful, and he grew immensely wealthy. He was the father of the "factory system," and was also the first to apply steam power to the operation of factory machinery.

Thus, in 1790, we find England the foremost manufacturer of yarns in the world, the inventor of the carding machines, the spinning jenny, the roller spinning machine, and the fly shuttle in the weaving looms. Her business men were alive to the opportunities before them and perfectly aware of the possibilities of the textile business. The British government had passed laws protecting "home industries" and forbade the exportation of any machine or pattern of any machine recently invented which might "then or thereafter be used in the woolen, cotton, or silk manufacture of the kingdom, or goods wherein wool, cotton, or silk were used, or any model or plan thereof." This law was rigidly enforced. The United States was recognized as an open port by England only for the sale of English manufactures, and England was open to American raw textile material.

But this condition was not long to continue. American inventors and capitalists were hard at work trying to solve the problem of the application of machinery to the textile industry. The farmers of the North and the planters of the South needed a home market for their wool, flax, and cotton, and capital needed that avenue for commerce.

In Massachusetts the Hon. Hugh Orr, in Bridgewater, financially assisted the Barr brothers in constructing a spinning jenny, stock card, and roving machine. In 1785 he helped Thomas Somers in building a machine similar to the Arkwright water frame, which became known as the "States Model," but was not sufficiently perfect to be practical. In 1787 a cotton factory of several jennies was started on the Bass River, in Beverly, Mass., and an attempt was made there and in Providence to operate a spinning mill at a profit. These, too, were failures, and Moses Brown of Providence bought the machinery. Mr. Brown was a student and financier who believed that sometime the great Arkwright secret must be discovered by American inventors, and he bought all discarded models with the hope that some useful principle involved might be saved. Mr. Brown had a deep interest in commerce and manufacturing, but in 1790 had practically retired, leaving large interests to his kinsman and son-in-law, Almy and Brown. This firm operated several branches of the textile business, among them a fulling mill, which stood where the southwest abutment of the Pawtucket bridge now stands, and in which most of the unsuccessful spinning machinery bought by Mr. Brown was stored.



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MODELS OF WHITNEY'S COTTON GIN AND HOWE'S SEWING MACHINE, IN THE NATIONAL MUSEUM, WASHINGTON

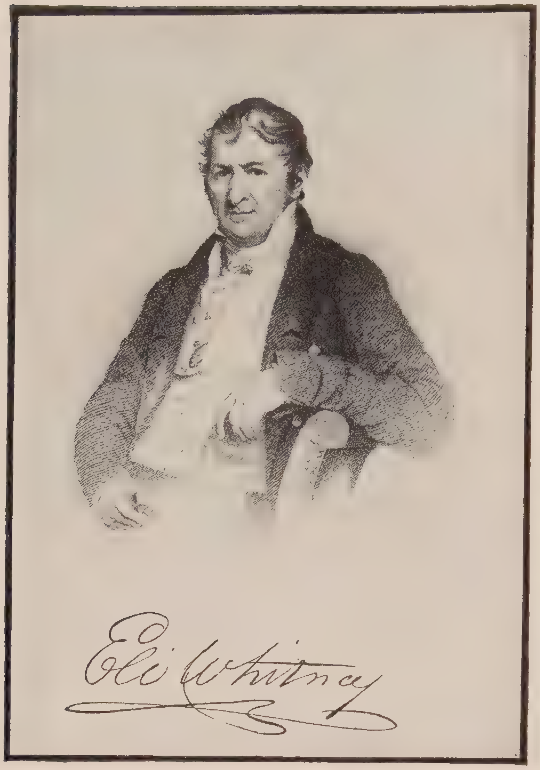
THE WEALTH-WINNING COTTON GIN

THE fabrics of olden times were woven mainly of wool or flax fiber. To-day cotton has largely taken the place of flax in many forms of manufacture the world over. The people of India have used cotton since the most remote times. The plant was introduced into America soon after its discovery by Columbus, but not until the beginning of the last century was it produced in any great quantity. Then the Southern planters found that they had just the climate for the growth of this plant and began to increase their crops of it. But the great trouble with the use of cotton for a fiber lay in the fact that it clung closely to the seeds and had to be laboriously separated by hand. This made its use slow and costly.

ELI WHITNEY'S EXPERIMENTS

Eli Whitney was a Massachusetts boy with a genius for mechanics. At the age of twelve he made a violin. A little later, in his father's absence, he took the family watch to pieces. After he had done it he was terror-stricken for fear he should not be able to put it together again. But he succeeded so well in doing this that his father never knew until told about it long years afterward. Through his industry and mechanical ability Whitney was able to earn his way through college, and later went to Georgia as a tutor. There he soon saw the difficulty with the cotton. Separating one pound of clean staple from the seed was a day's work for a woman. Whitney thought he could devise a machine which would make this work much easier, and he accordingly went about it. Another Yale graduate, Phineas Miller of Connecticut, lived near by and gave the young inventor substantial encouragement. Whitney had to make his own tools and draw his own wire for the invention, but he persevered, and by the end of the winter of 1793 the two were sure of the success of their machine.

As with most great inventions, the principle was a simple one. The machine consists of two cylinders mounted in a strong wooden frame, one bearing a series of tooth-like spikes fitting into grooves in the other. The other is mounted with brushes which touch the tips of the spikes. The cotton is dropped into a hopper, is seized by the spiked cylinder, torn from the seed, and brushed into a con-



From “ The Story of Textiles ”

THE INVENTOR OF THE COTTON GIN

Though made famous by the cotton gin, Whitney gained nothing in a financial way from this epoch-making device. Fortune came to him later in his career from his inventions connected with the manufacture of firearms.

venient receptacle. The seeds remain behind, as they are too large to go through the bars through which the saws drag the cotton. Such was the first machine. Many improvements have since been made, but in the year when the patent was taken out on that first machine the cotton crop of the South was but ten thousand bales. In fifty years, thanks almost entirely to Whitney's cotton gin, the crop had increased to many million bales. In 1860 the export amounted to four million bales.

This talented young mechanic thus added hundreds of millions to the wealth of his country; but he had to fight against chicanery and theft, and become involved in countless lawsuits and vexations, to retain even a trifling part of the value of his patents, so ungrateful is man. To his honor it should be said that he bore it all with patience, asserting his rights perseveringly and with unruffled good will.

THE ROMANCE OF THE SEWING MACHINE

ALL labor-saving machines have been received with distrust by the very people to whom they were to bring the most help. Crompton, Arkwright, Hargreaves, Jacquard, inventors of textile machinery which has been a priceless boon to mankind, were all mobbed and persecuted. Hand weavers and spinners were furious that inventions should be made which would, as they thought, take away their opportunities to work. Thus Elias Howe, who took out the first United States patent and became the first United States sewing-machine inventor of record, although he had in mind the greatest labor-saving device ever introduced

From “ Inventors.” Copyright, Charles Scribner's Sons

ELIAS HOWE

This humble machinist and persevering inventor lived to receive many honors, including the Legion of Honor cross.

into the household, was abused and denounced as the enemy of man. But he persevered. Like Whitney of the cotton gin, he was a Massachusetts boy. He grew up a machinist, married, and had three children. His wages in the machine shop were small. He was frail, slightly lame, and poor. His wife sewed evenings to help keep the wolf from the door, and watching her toil bred in his heart the desire for a machine to lighten such labor. Taking counsel of no one, he worked upon this idea for a long time, setting up his shop in a garret of his father's house. He was so poor that often he lacked money to buy the iron and steel needed for his work on his models.

Howe made a machine which he knew would work, but he had not the money to complete it or to find a market for it. So perhaps we owe the modern sewing machine nearly as much to a coal and wood dealer of Cambridge, Mass., named Fisher, as to the inventor. Fisher took Howe and his family into his own home, provided a workshop, and lent Howe five hundred dollars for the construction of a first machine. In return Fisher was to be a half owner. It was in 1845 that Howe completed and patented his machine, which combined many novel devices. One of these, putting the eye of the needle at the same end as the point, had already been introduced in a sewing machine invented by two Englishmen. But Howe used it in a new combination, the needle being grooved and vibrating lengthwise, while a side-pointed shuttle whipped back and forth through the thread and locked the stitch. His first idea had the eye in the middle of the needle, which was double pointed and went back and forth through the cloth. Howe sewed with this first machine two woolen suits, one for himself and one for Fisher, the machine doing strong and accurate work.

But while all acknowledged that the machine was effective, no one would believe in its usefulness. He offered it to the tailors of Boston, and they told him it would ruin their trade. No one would invest a dollar in it. Fisher got discouraged and withdrew. Howe lost his position, went to England, where he worked for an umbrella maker for fifteen dollars a week, and tried to market his invention there. No one would buy it, but unscrupulous mechanics pirated his ideas and made machines of their own. He came back to Boston, arriving without money, just in time to see his dying wife. Then the ship in which he had sent home his household goods went to the bottom.

DEMONSTRATION OF FIRST SINGER SEWING MACHINE AT NO. 323 BROADWAY, NEW YORK

Copy of illustration published in August, 1853.

But this was his darkest hour. The English pirates had succeeded in bringing his machine to the notice of the newspapers, which called it a wonder. His patent was strong and he found money to defend it, and in 1850 he began to manufacture the machines in a small way in New York.

Meanwhile other inventors were at work. In 1851 A. B. Wilson, a Michigan cabinet maker, also constructed a sewing machine, although he had never seen one. This had some ingenious improvements upon Howe's machine. Wilson was the most original and had perhaps the finest inventive genius of any of the sewing-machine inventors of his day.

At about the same time Isaac M. Singer patented the first "rigid-arm" sewing machine and made important improvements in the shuttle. Mr. Singer was born in Oswego, N. Y., October 27, 1811, and was early apprenticed to the trade of machinist. He spent years of study on the original sewing machine, which he was sure could be improved. Finally he obtained a patent on a single-thread, chain-stitch machine and built a factory. He made a fortune, as he deserved to, and died in Torquay, England, in 1875. The Singer machine has formed the basis for all sewing machines manufactured since his revolutionary improvement was patented.

It was not till 1855 that Howe found the tide of fortune turning in his favor. Even then the garment workers denounced him and there were riots at the places where the machine was used. Besides this the other inventors of sewing machines had started manufacturing them. Lawsuits over patents ensued, and there was much bitterness of feeling between the rival companies. But these differences were all finally settled. Howe's royalties increased in six years from $300 to $200,000 a year. The poor mechanic had made his fortune and done his share in conferring an inestimable boon on the households of the world.

The companies founded by Isaac Singer and by Wheeler and Wilson greatly prospered, and are to-day among the world's chief producers of sewing machines. In fact, taking into account the numerous American companies now manufacturing sewing machines, the United States leads the world in this industry, both in quantity and quality of output.

In the comparatively few years since the practical value of the sewing machine was realized, hundreds of inventive minds have turned their thoughts toward the possibilities of improvement. Thousands of patents have been issued in Europe and America for devices that have increased its efficiency and usefulness, but it is a tribute to the thoroughness of its original inventors that the sewing machine to-day still operates on the basic principles which they laid down.

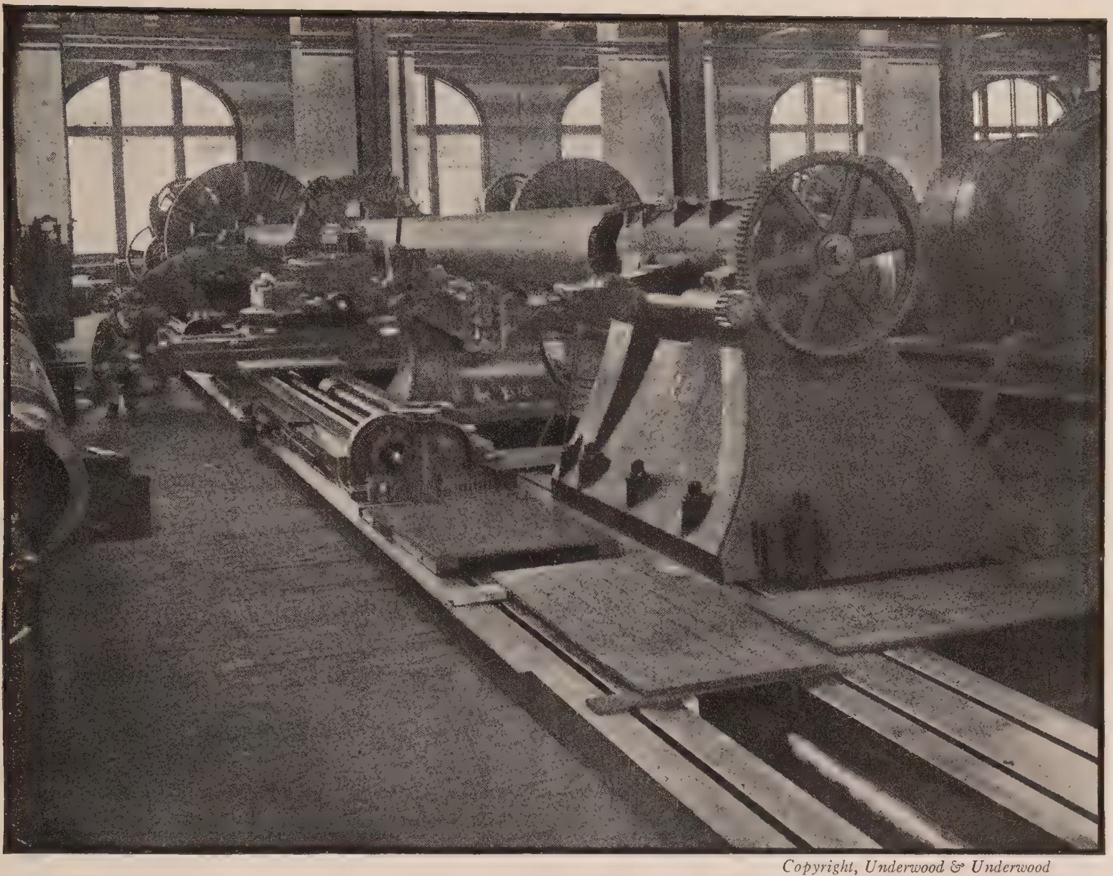
USES OF THE SEWING MACHINE

When you hear the hum of a busy sewing machine in a quiet room of your own home, do not be misled into thinking that mother's or sister's mysterious work with filmy fabrics is the only use to which these machines are put. Will you not be surprised to learn that over two thousand different sorts of sewing machines are made, and that they play an important part in many great industries? The clothing, hats, and shoes which you wear are probably machine-sewed. The delightful embroidery which adorns ladies' clothing is often worked by ingenious machines, while the buttons are sewed on by others just as interesting. The making of buttonholes, formerly a tedious operation only to be performed by hand, was turned into a mechanical process by John Reece, of Boston, who half a century ago invented a machine which would cut and work buttonholes at the same time. The labor of operating sewing machines by foot power has been done away with by the application to them of electric motors. Nowadays, even the sewing machines used in the home are powered by small motors, which are in turn controlled by a gentle pressure of the foot or knee upon a switch.

THE KNITTING MACHINE

As long ago as 1587, an English clergyman named William Lee invented a machine which would knit stockings and hose. It may have been this device that first gave inspiration for the invention of a machine which would sew. The English government refused patents on the ground that such a machine as Lee's would throw many hand knitters out of work. Lee persevered to the extent of starting a small factory, but continually beset by workers who felt that such a machine would deprive them of a living, he was forced to abandon his efforts and died penniless. Nevertheless, from this unfortunate man's struggles was born the knitting industry which to-day forms so important a portion of our textile manufacturing business.

Strange to say, it was another clergyman, Isaac W. Lamb, of Michigan, who carried on the work of Lee nearly three centuries later. As a boy he invented a machine for braiding four strands of leather into the form of a whiplash. This first device was developed into a knitting machine which could handle both flat and tubular work. His machine was patented in 1863. Low-priced sweaters, stockings, underclothing, and many other articles of utility and comfort are products of the knitting machine.



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LARGE LATHE FOR TURNING GREAT GUNS

THE DEVELOPMENT OF SPECIAL MACHINERY

MACHINES FOR MAKING MACHINES

IT will have already occurred to our readers that the making of machines must of itself employ many men and much capital, and this is indeed true. Skilled machine-shop mechanics are among the most highly paid workmen in the world. The machines that are used in making machines are among the most perfect. For just as a shift of the fraction of an inch in the pointing of a gun will send the bullet wide of its mark, so trifling inaccuracies in these machines for making machines would produce most disastrous results. In fine machine work it is common to demand accuracy to one-thousandth of an inch, or even less.

There are many forms of gauges, or micrometers, for measuring to minute fractions of an inch. One of the most usual types is that illustrated in our drawing, *D*, on page 27. It will measure to the ten-thousandth of an inch. The measurement is made by dividing the pitch of the thread of the adjusting screw by the fraction of turn given in making the measurement. If one complete turn of the barrel moves the gauge one-thousandth of an inch, one-tenth of a turn will move it one ten-thousandth of an inch. Of course the machines are set by similar devices. But the workman does not depend upon this setting of a machine. He continually tests his work with his micrometer caliper.

THE LATHE

This is one of the most important machines in a machine shop. A lathe is a machine for turning the work against a fixed tool. A steel-working lathe moves very slowly. The tool is held in an adjustable rest, and the work is revolved by a headstock on which a variety of chucks for holding the piece may be used according to the need of the work, or the piece may be held between two centers, one in the headstock and one in the tailstock. Much time is spent in making the adjustments, after which the machine takes care of itself. As most machinery is made up of revolving, that is cylindrical, parts, the use of the lathe is very extensive. Lathes are made to turn the smallest axles for fine watches and also to turn huge cannon of eighty or one hundred tons of the hardest steel. There are few more fascinating sights, to one interested in mechanics, than a lathe at work peeling long ribbons of steel from a great shaft or tiny, almost invisible, hairs from some exquisite little pin.

THE MILLING MACHINE

The milling machine is the machinist's man of all work. The illustration on page 27 shows what is called a "Universal Milling Machine." It has a table for the work, arranged with "feeds," by which all classes of plane, circular, helical, index, and other milling may be done. On such a machine a piece of steel may be rounded, a thread cut, and a slit made in the head, for a screw, with one setting of the machine. It seems to have no limitations of capacity. A milling machine differs from a lathe in that the tool is a revolving cutter against which the work is pressed, while in a lathe the tool is a fixed edge or point against which the work turns.

THE PLANER

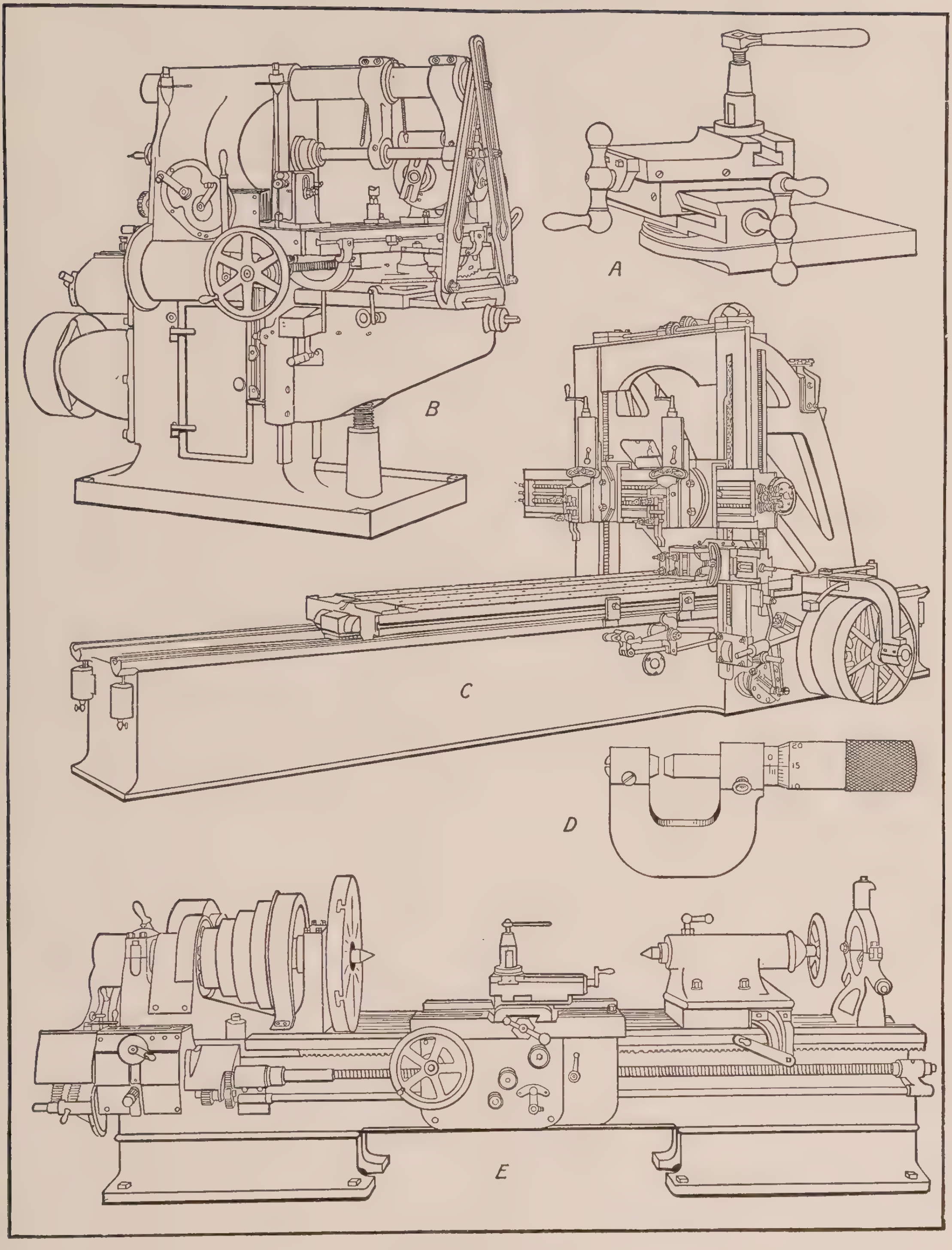
This is a machine for producing plane surfaces on metals, and is also shown on page 27. The work is held on a table which runs back and forth under the tool, which is stationary. This cutting tool shaves off successively, side by side, thin strips of metal, until a perfectly flat surface is produced. The machines are found in varying sizes. On the larger ones the tables are from seven to eight feet in width and twenty feet long. While the uses of the planer are not as varied as the milling machine or the lathe, it has many adjustments that in the hands of an ingenious and skillful workman produce an amazing variety of work.

Of course there are many varieties of this as of other instruments. Our illustration shows only the most usual type.

Drills, forges, cutters, and other machines are used, but the three great machines above described, with micrometer calipers for purposes of measurement, are the foundation of machine-shop work. Many automatic machine tools are also used which need almost no attention.

THE MARVELOUS DEVELOPMENT OF SHOE MACHINERY

THE first machine to be widely accepted by the shoe manufacturers was the rolling machine. This was used for rolling the sole leather under pressure, and it is said that a man could perform in a minute with this machine the same office which would have exacted half an hour of his time with the old lapstone. Elias Howe's sewing machine, of which we have already given an account, was soon followed by a machine for sewing with waxed thread. But the real revolution in the manufacture of shoes came in 1858, with the invention of the McKay sewing machine. The inventor of this machine was Lyman P. Blake. The McKay machine did not at this time sew the toe or heel, but the sewing started at the shank and was carried forward to a point near the toe, first on one side and then on the other. The financial difficulties of promoting the use of this machine led to the invention of the royalty system. Stamps were sold to be affixed to each pair of shoes made by the machine. The plan was wonderfully successful. In 1862 an inventor named Matthias, working for Mr. McKay, devised a machine for sewing clear around the toe. This was first used by Gilmore Brothers in filling a contract for army shoes. The entire sole was sewed round and round, as if it were quilted, the sewing beginning at the edge and ending in the middle. It was a very crude machine, but the shoe was a success, and the McKay machine was established as an economic necessity. It has since been greatly improved.



MACHINE-SHOP MACHINERY

A. Tool rest or holder used on lathe. *B*. A milling machine. *C*. A planer. *D*. A micrometer caliper. *E*. An engine lathe.

The inventor of the Goodyear welt machine was a New York mechanic named Auguste Destoye. His machine was not a success, although he furnished the fundamental idea. Mr. Charles Goodyear became convinced of its practicability and engaged other mechanics to work on it, at last producing a machine for sewing, first, turn shoes and finally welt shoes.

The invention of a machine for making shoe tacks seems like a small thing, but it has made many fortunes. Large shoe manufacturers buy tacks by the ton. The industry is still centered near Bridgewater, Mass., where it originated. Mr. Goodyear added to the machines for doing parts of the work on welt shoes. He devised machines for stitching the insole to the outsole, for channeling the insole and outsole, for automatically leveling, etc. His machines constituted a system, known as the welt system, and it is this system that has been the subject of constant improvement.

Mr. Matzeliger, a Lynn inventor, devised what is called the "hand method lasting machine." By this invention almost the last trace of hand work disappeared from the manufacture of all but shoes for special trade. The American machine-made shoe is one of the greatest triumphs of the Age of Machinery. (How shoes are made is described on pages 241–245.)

AGRICULTURAL IMPLEMENTS

WHAT has machinery done toward feeding mankind? Not as much, in some ways, and yet more than we would believe without careful study.

As we realize that the greatest nations have been agricultural, we may well wonder how the ancient farmers accomplished so much with their primitive tools — the crude plows, sickles, and scythes. Agriculture was the hardest kind of manual labor. The strange thing is that conditions remained practically unchanged for thousands of years; and the farmers of Europe, and of our own country as well, down to the middle of the last century, were still using the crude tools of the ancient Egyptians and Israelites. Invention at last turned its attention to the farm, and by 1850 a new era had begun, with the introduction of agricultural machinery. To-day machines in great variety and of wonderful inventive genius are in use in all the operations involved in soil preparation, planting, harvesting, and marketing the products.

TILLAGE MACHINERY — PLOWS

The chief implements for preparing the soil are plows, harrows, and cultivators of various kinds. The plow turns the furrow completely over and exposes the soil to the air. The first plow was simply a form of hoe made from a crooked stick. Then larger plows were made and horses and oxen were set to draw them. Nowadays plows, harrows, and cultivators have all been adapted to use of power. Early plows were made of wood plated with iron, and, strangely enough, no great improvements were made in them through the centuries. Daniel Webster is said to have designed a large and clumsy plow for his Marshfield farm. It turned a furrow eighteen inches wide and required several men and a yoke of oxen to operate it.

Steel plows were first introduced when farming in America moved farther west and the settlers were obliged to wrestle with the tough sods of the prairie states, with which the old iron-plated plows were unable to cope.

Walking plows are made to cut furrows from eight to eighteen inches. A plow cutting a fourteen-inch furrow is considered a two-horse, and one cutting a sixteen or an eighteen inch furrow a three-horse plow. The name "sulky plow" is used for all wheel plows, but applies more particularly to single plows; while the name "gang plow" is given to double or larger plows. Gasoline tractors are now used instead of horses on almost all large farms.

HARROWS AND CULTIVATORS

After plowing the ground it is necessary to pulverize the soil very finely before putting in the seed. Harrows and cultivators are the implements used for this purpose. The most common type of harrow is the smoothing harrow, made usually with straight, fixed teeth of wood or iron. The spring-tooth harrow has curved teeth, which spring back and are released when caught on any obstacle. It is very useful for stony ground and is also an excellent pulverizer. But the most useful of all harrows is the disk harrow. On account of its rolling action it can be used for many different conditions, and by some practical farmers it is made to take the place of the plow itself.

After the soil has been smoothed by the harrow, the cultivator does its part in making the furrows for the planting of the seed. And after the seed has been planted it performs the same service as a hand hoe in keeping the soil in good condition.

PLANTING THE SEED

The old way of sowing seed was by hand. Now we have various kinds of drills, broadcast sowers, and seed barrows. Drills deposit the seed in rows, below the surface, while broadcast machines and seed barrows scatter the seed on the surface or on furrows.

An important machine called a "corn planter" is strictly an American invention, for corn or maize is peculiarly an American crop. In some states the device has proved a valuable aid to the farmer. For small crops, hand planting will probably give the best results, but on large tracts of land, in regions where wages are high and time is an important factor, advantages attach to the use of the machine.

CUTTING ENSILAGE CORN AND FILLING A SILO BY MACHINERY

Ensilage is green fodder preserved for winter feeding by compressing in a silo and keeping from the air.

HARVESTING AND THRESHING

It is in the field of harvesting and threshing machinery that the greatest advance has been made over the early farming tools. There are in this class harvesters, self-binders, reaping machines, headers, combined harvesters and threshers, mowing machines, loaders, stackers, swath turners, horserakes, hay tedders, etc.

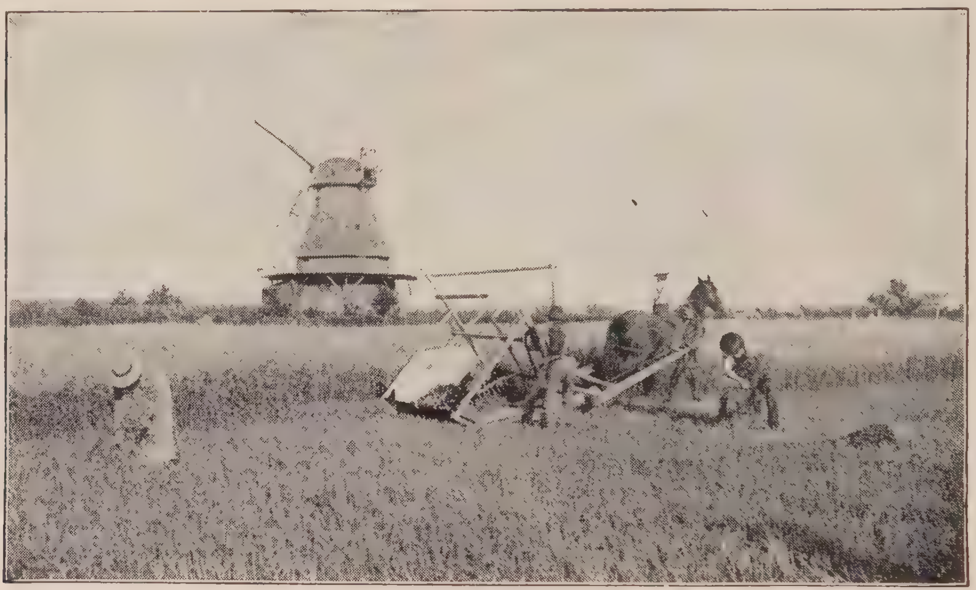
Flailing was the common method of threshing grain as late as 1850, but treading with animals was a method also much used. The flail was simply a short club, usually attached to a handle by a piece of leather. After the grain was beaten from the head or ear with the flail, the straw was carefully raked away and the chaff separated from the grain by fanning or by letting the wind blow it out.

The modern threshing machine is a highly ingenious and complicated invention which shells the grain from the head, separates the straw from the grain and chaff, extricates the grain from the chaff and dirt, and finally delivers the grain to one place and the straw to another.

The machine for reaping the grain, however, has achieved the greatest wonders in modern farming. Think of the immeasurable difference between the sickle and cradle and the modern reaper! The sickle, as we know, was used from time immemorial as a harvesting tool, the scythe being a slight improvement upon the sickle. The cradle was an American device long in use. This, too, was an improvement over previous implements. It consisted of a series of finger-like rods to be attached to the scythe, and was designed to lay the grain in an even swath. In 1834 came the reaper, one of the most important inventions ever given to the world, the machine that, for the first time in history, *made bread cheap*.

THE MACHINE THAT MADE BREAD CHEAP

OVER thousands of square miles of our Western prairies the wheat grows, waving in the wind like a golden sea. It is a world of wheat in which often the eye sees no other horizon, an ocean of verdure which is destined to feed the world with its golden grain. Without the wheat of the Western prairies, famine would stalk the land the world over. And without the reaper the golden grains would rot in the fields, for nowhere could be found sufficient labor to harvest it by hand in the primitive way which was common little more than a half-century ago, a way that was the only one from earliest ages until a Virginia lad, son of a farmer, made a mechanical reaper.



Courtesy of International Harvester Co.

THE McCORMICK REAPING MACHINE OF 1834

THE STORY OF ITS INVENTION

Cyrus Hall McCormick was brought up on a farm. As a boy of fifteen he was accustomed to go into the wheat fields and "cradle" the grain with the hand reaper, and it is worthy of note that at that age he constructed a superior hand implement by means of which he was able to harvest as much wheat as a full-grown man.

But his father was more than a farmer. He had a large workshop on the place, a saw and grist mill, and smelting furnaces. In all these young McCormick learned practical mechanics and made several minor inventions. One of these was a plow which threw furrows to the right or left as desired. But as he grew up he became absorbed in a desire to invent a mechanical reaper. His father had tried this and had failed, losing much money by his experiments, and he discouraged the boy. But young McCormick persisted. He found that his father's machine would cut grain that stood perfectly straight in the field, but he knew that a practical machine must cut grain whether it stood straight or was beaten down — lodged — by the rain and wind. The grain must be cut, stalks and all, no matter how it might happen to stand.

In his father's shop he worked patiently, making every part of the machine himself, whether of wood or iron, and he finally produced there in 1831 the first reaper that ever really cut an average field of wheat satisfactorily. The four great essentials were those of the machine of to-day: a vibrating cutting blade, a reel to bring the grain within reach of the blade, a platform to receive the falling stalks, and a divider to separate the grain to be cut from that to be left standing. This machine was drawn by horses and its work astonished the farmers who saw it in operation. With it one man could do the work of many and the problem of handling the great wheat fields of the future was solved.

From the little blacksmith shop on the Virginia farm the making of McCormick reapers has grown to a vast industry. Reapers based upon the McCormick patent are at work in wheat fields of the world, not only on the great prairies from Texas to the far Canadian Northwest, but watched with awe by the natives on the steppes of Russia, and in India and Egypt. For the use of the reaper vast wheat fields are planted in Argentina and Australia. The reaper is one of the labor-saving wonders of the age. It has kept millions of men from drudgery and millions more from famine. It is estimated that the use of the reaper increases the world's wealth by hundreds of millions of dollars every year.

PROGRESS IN PRINTING

THE big glistening machines which roar and clatter in our print shops are the product of many useful ideas contributed by hundreds of printers down through the ages. Some of these men we will mention by name in this story of the graphic arts — Gutenberg, Senefelder, Levy, Koenig, Nicholson, Miehle, Franklin, Mergenthaler. Many others are lost to us for all time — men whose ideas were used but who never became famous.

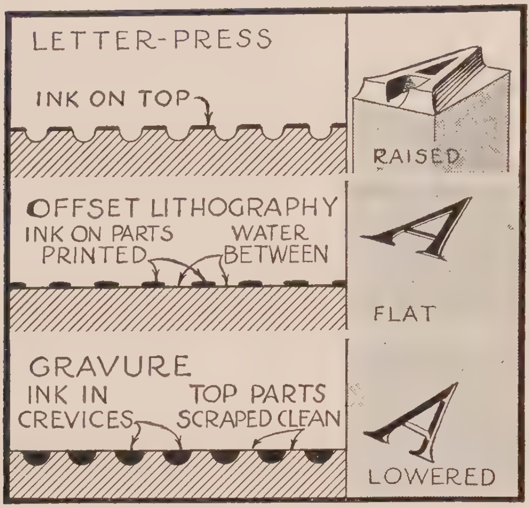
Every printed word you read and every printed picture you see is the product of one or another of three general ways of printing on paper with ink — letter-press, lithography, and gravure. Remember these three terms, as we will discuss them more fully.

The early Chinese discovered that if paper were laid over a carved surface and rubbed with a pencil, an impression would be left on the paper. Later, they found that watercolor inks could be similarly transferred to paper from a carved surface. They became very skilled at printing pictures in various colors from carved wooden blocks. The earliest known book dates back to the year 868 A.D., and was printed by Wang Chieh in memory of his parents.

European scholars were working separately on ways to produce books without the painstaking hand lettering and drawing by which the medieval monks made their Bibles and prayer books. Their printing developed very slowly, however, because every page required a plate which had to be carved by hand.

The invention of movable type overcame this obstacle. Though the Chinese used separate wooden characters to compose pages as early as 1041, our first authentic record of the European use of movable type is the famous 42-line Bible (so-called because it has 42 lines of type in double columns on each page), printed by Johannes Gutenberg of Mainz, Germany, and dated August 24, 1456.

The movable type principle is simple and remains the same to this day, although with many refinements. Each letter is carefully cut or stamped in some kind of durable metal, generally brass. This mold, or matrix as it is called, is then used to cast as many duplicates



THREE KINDS OF PRINTING

of the letter as are required. A complete set of type is called a font. The individual letters are set up side by side, or composed, into words and lines to form each page. After the page has been printed, the letters are put back into their proper compartments in large storage trays, ready to be used again.

Both the Chinese and the Europeans carved illustrations on blocks of wood and combined them with type into forms to produce illustrated books. The forms were first inked by brushing, then later by daubing them with a ball made of a leather bag stuffed with feathers and coated with lamp black finely ground in linseed oil varnish. This method of printing is known as letter-press printing and is still the most widely used process.

Another form of printing from a carved surface had its beginnings among the artists of medieval Europe. They discovered that depressions carved in a smooth metal surface could be filled with soft ink and the ink then transferred by pressure to a piece of damp paper to obtain a picture. This method, known as intaglio printing, is still used today by artists to achieve special types of pictures, and our gravure process (more familiarly known as rotogravure) is simply a refinement of it.

It was also in the field of fine arts that lithography (Greek for stone-printing) was invented. In 1818, a Bavarian named Alois Senefelder discovered that fine-textured limestone could be polished smooth, drawn upon with grease crayon, then dampened with water, after which it could be inked and pressed against wet paper to produce a duplicate of his picture. The position, of course, would be reversed as in all printing, so the drawing would have to be made in reverse. The greasy portions of his plate received the ink; the wet parts repelled it so that those parts, though coming in contact with the paper, would leave the paper white.

Later, commercial printers found that if the ink were first transferred to a rubber blanket right from the stone and then printed, or offset, on paper, a much softer grade of paper could be used and special effects could be obtained. The rubber blanket also made it possible to print on metal and other surfaces that are otherwise hard to print on. Offset lithography is used to decorate cans, decalcomania transfers and many other objects. It is also used to print the outdoor posters we see along our highways. It is still called offset lithography, though stones are no longer used.

When photography was invented, its principles were soon applied to printing. A Philadelphia engraver, Max Levy, discovered in 1893 a method of cutting fine parallel lines in sheets of plate glass, then filling those lines with black paint. He found that by binding two such sheets of glass together face-to-face so that the lines crossed, a screen was made that could be placed in a camera so as to break up the image into rows of tiny dots. The image thus made could then be transferred photographically from the negative to a sheet of copper which had been coated with a light-sensitive substance. Next, the copper surface could be etched, or eaten away with acid, in such a way as to leave the dots raised. These raised dots then would print a picture.

Examine closely any printed photograph in a newspaper, and you will find that the various shades of gray which make up the picture are actually slanted rows of dots. The large dots make dark areas; the small dots produce lighter areas. The eye blends them together so that we see them not as dots but as a picture.

These dot pictures are called "halftones" because approximately half the picture area is solid black dots and the spaces between the dots remain white. The halftone screen is used in the preparation of plates for letter-press, offset and gravure.

Shortly after the invention of the halftone screen, it was discovered that the primary colors in any colored picture could be photographed separately in three different exposures, by using light filters before the lens of the camera to filter out all but the color wanted. Then these three negatives could be used to produce halftone plates for printing yellow, red and blue over each other to make a reproduction of the picture. The piling up of the three colors blends them, very much like the blending of your water colors, to produce green from yellow and blue, purple from red and blue, orange from red and yellow, and brown from all three. A fourth plate is now generally made to add black, because this seems to make the picture more life-like. The principle of four-color-process has been applied extensively to all three forms of printing — letter-press, offset and gravure.

PRINTING PRESSES

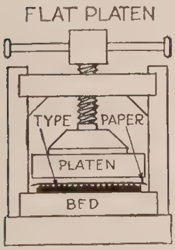
With the coming of steam power and its many new mechanical principles, printers rapidly invented improvements to make their books and papers available to more and more people at prices which the masses could afford.

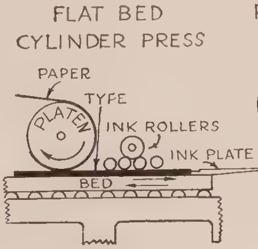
The first printing presses had only the basic features—a bed, for the type to rest on, and a movable flat plate, known as a platen, to press the paper against the type with high pressure. The early platens were driven by screws, like the movable jaw of a vise. (See pages 10 and 11.) In Franklin's press this was done much faster by a system of levers and toggles. These elements of bed and platen are necessary to all presses and our progress in printing has consisted largely in changing the design and adding devices to make the work more rapid.

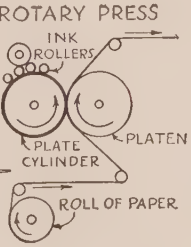
For many years after the construction of the first all-iron screw press by Charles, Earl of Stanhope, all presses had flat beds and flat platens. Then, in 1790, a press with a cylindrical platen was patented by William Nicholson. The type bed remained flat, but the paper was rolled over the type to make the impression. After a substance had been found that was soft enough to be cast into rollers and used instead of daubers for inking the type, the work was again speeded up. With the use of steam power, first applied to printing by Frederick Koenig (working in England) the number of copies that could be printed in an hour rose to 1100. A further improvement in this type of press, designed in America by Robert Miehle in 1883, is in wide use today for fine printing, but does not produce many more sheets per hour than Koenig's steam press.

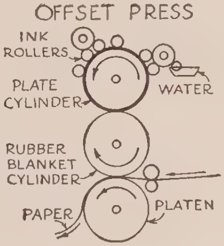
In 1868, the London Times installed a press in which both bed and platen were cylinders, revolving against each other with the paper between them. This allowed a continuous motion, requiring less power and producing much greater speed. Because type could not be set on a round surface, curved printing plates were cast which could be mounted on the cylinder. These curved plates, or stereotypes, remain to this day. They are made by taking a deep impression of the type on heavy, pulpy cardboard, curving the cardboard, or mat, into a mold, and then casting type metal into it, to form a one-piece curved metal plate having all the type for a whole newspaper page on its outer face.

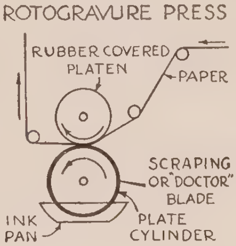
By combining several presses which print both sides of the sheet at once, and by feeding











them from continuous rolls of paper, magazines and newspapers can be printed by the hundreds of thousands and delivered to readers only a few hours after the events they tell about.

The modern offset press, though not as large as a big newspaper press, is perhaps our most complicated printing machine. Beside the cylinders which carry the plate and the paper, there must be another between, bearing the rubber blanket to transfer the image to the paper. There are so many rollers involved in providing both ink and water in just the right amounts that one can scarcely see the actual printing operation going on. These mighty machines have many delicate adjustments and can be successfully operated only by experts.

The rotogravure press is like other kinds except that, since the ink must come only from the etched holes in the plate, the smooth top surface must be perfectly clean. This is accomplished by scraping the surface, after inking, with a thin, sharp knife edge known as the "doctor" as the cylinder rotates.

Many variations on the fundamental types of presses are now in use and designers have added many automatic devices for saving hand work, such as mechanisms to feed the sheets of paper in and stack them up after they are printed, ink fountains for regulating the flow of ink into the rollers, burners which pass a gas flame over the wet surface to hasten drying, and sprayers which inject small particles of quick-drying fluid between the sheets to separate them as they pile up and keep them from transferring their ink onto each other.

TYPESETTING MACHINES

Not only has the slow little hand press been superseded by the great power press, but typesetting by hand has largely given way to typesetting machines. These machines do not literally set type. They cast new type from brass molds, while the typesetter merely presses the keys of a board similar to that of a typewriter. There are two kinds of typesetting machines—the linotype and the monotype. The linotype casts a line of type in one solid piece of metal, while the monotype casts each letter separately.

Ottmar Mergenthaler, an American, invented the linotype in 1885, and it has been improved since then until now the machine does the whole job automatically. When the operator types on the keyboard, brass matrices drop into place to spell out the words of an entire line. Then type metal flows from a melting pot into this line of letters and hardens. The result is a single bar, or "slug," of metal with an entire line of raised letters on it. Finally, the matrices are returned automatically to their storage bins at the top of the machine.

The monotype machine makes individual pieces of type, so that if the operator makes an error, he need only replace one character, whereas the linotype operator must replace an entire line. Two machines are used in the monotype method. On one, equipped with a keyboard, the operator types out the copy and his typing is recorded on a paper ribbon, like a player piano roll. At the end of each line, a revolving drum swings around automatically to show the operator the correct spacing of the full line. When this ribbon is run through the casting machine, the characters are cast individually and the words are so spaced that they fill up the total width of the line. This produces better spacing than is obtainable with either foundry type or linotype.

The binding of books, magazines and pamphlets requires many machines which in themselves are marvels of modern invention. Most printing is done on large sheets of paper. Sixteen or thirty-two pages are printed on each side of the sheet, then the sheets are automatically folded so that the pages will fall in their correct positions. This means that from one large sheet of paper, printed on both sides, the printer obtains either thirty-two or sixty-four pages of a book. The folded sections are later gathered into piles, each one a complete book, sewed together by a special machine, trimmed at the edges, and glued into the cover to produce a bound volume.

If you wish to see in action some of the hundreds of different machines used in the printing industry, you might go to a newspaper plant, a print shop, a bindery, and a photo-engraving plant. Printers are proud of their marvelous machinery and will generally furnish a guide to explain the various processes.

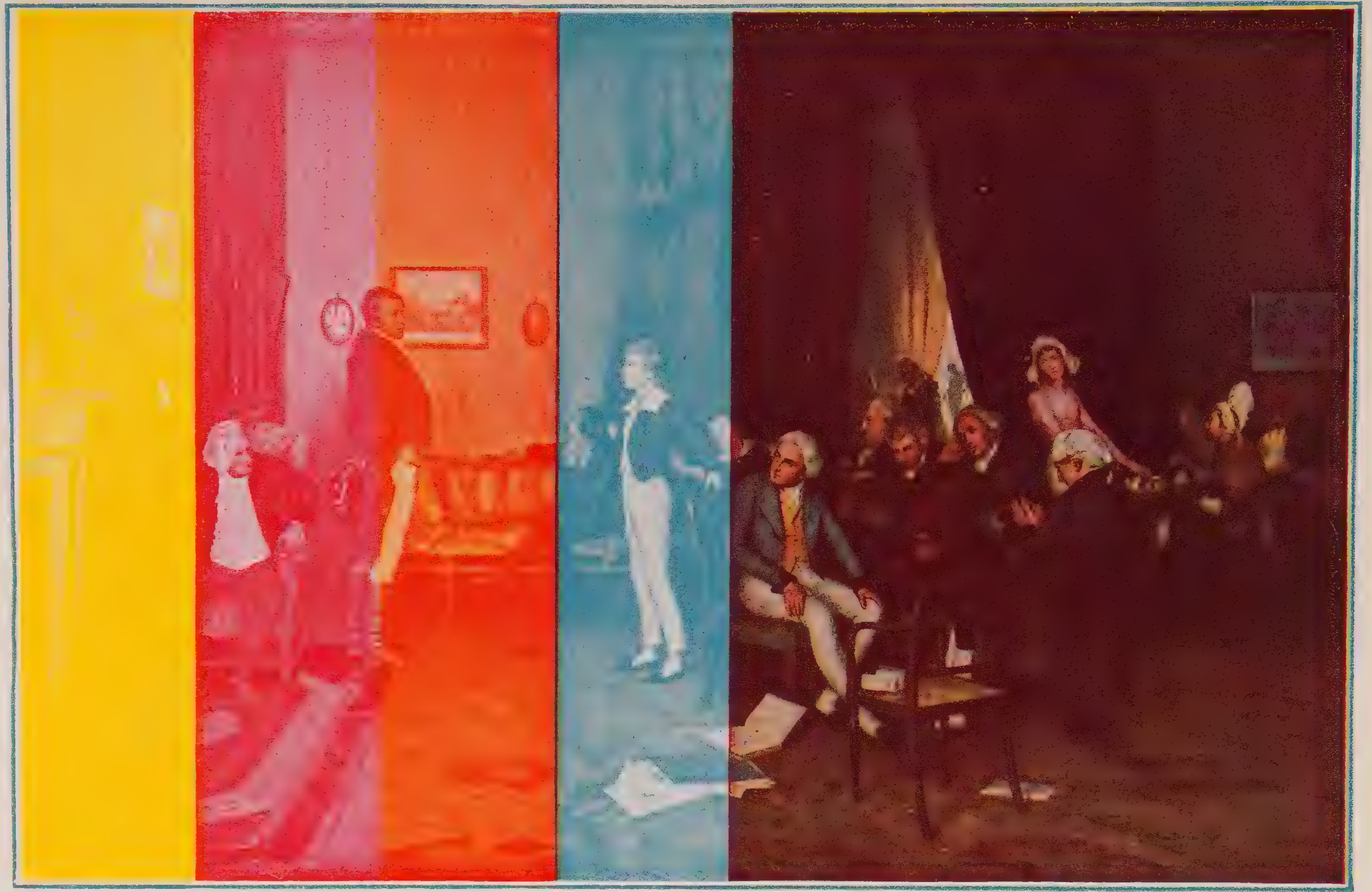


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DIAGRAM SHOWING THE PROCESS OF MAKING A THREE-COLOR PLATE

Yellow plate used in first printing.

Red plate used in second printing.

How picture looks when red has been printed **over yellow.**

Blue plate used in third printing.

Completed picture with blue printed over yellow and red.
For full three color picture see page 207, Vol. VIII

Courtesy of National Academy of Sciences

THE MARCH OF SCIENCE

By Mary Ellen Whelpley

ARCHIMEDES

(287–212 B. C.)

IF you had lived in Syracuse about the third century B. C., you might have been astonished one day to see a man almost naked running through the streets toward his home crying, "*Eureka! Eureka!*" "I have found it! I have found it!" You might have laughed and wondered what Archimedes the mathematician had found. It probably would not have occurred to you that more than two thousand years later people would still be talking about that incident.

It had happened that King Hiero wished to have a particularly beautiful crown to lay on the altar of the gods. He had given the gold for the crown to a goldsmith with directions for its making. When the crown was returned to him, there were rumors about the court that the goldsmith had kept some of the gold for himself and put in cheaper silver. But unless the king wished to melt the beautifully wrought crown he could not know for certain whether it had been made of pure gold or not.

In this quandary he consulted Archimedes. But the great mathematician could not tell him any way in which to discover the truth. However, Archimedes went away thinking about the problem. There must be an answer. And of course there was. That answer came to Archimedes as he was stepping into the tub at the public baths. The water overflowed. Then he noticed that the deeper his body sank into the water, the more water ran out of the tub. So excited was he that he leaped out of the tub and dashed home without waiting to clothe himself.

He had suddenly realized that the exact amount of water which ran out of the tub must be in proportion to the size of his body and that this was related to the weight of his body. Every substance must have a certain size in proportion to its weight. It took only a short time to weigh a piece of gold and a piece of silver. Each one in turn went into the water. Since silver is the lighter metal, the silver piece weighing the same as the gold one was larger and therefore displaced more water. Archimedes then weighed the crown and put it in the water. By noting how much water it displaced and comparing this figure with those taken in the first experiment, he found that the crown was larger than it would have been if it had been made of pure gold. The dishonesty of the goldsmith was revealed. But more important,

To help in identifying the scientists, a brief account of each is given in connection with his picture, even though a longer account appears elsewhere.

Archimedes had discovered the great principle that "the weights of bodies of the same substance are proportional to their masses."

This was only one of his important discoveries. You will read about some of his other achievements on pages 5 and 14 of this volume. (He may be seen in the group in Volume I, page 263.)

HUYGENS

(1629–1695)

CHRISTIAN HUYGENS made some of the earliest pendulum clocks. Although Galileo had pointed out that the even swing of a pendulum might regulate the works of a clock so that it would keep accurate time, he died without seeing his idea carried out.

Huygens was born at the Hague, Holland. As a boy he was most interested in the study of mathematics, and he also loved to tinker with every bit of machinery that he could get his hands on. When he was sixteen, he went to the University of Leyden where he made an excellent record both in mathematics and astronomy. By the time he was twenty-two, he had written several very good papers on geometry.

It was when he was observing the heavenly bodies that he realized the necessity for some means of measuring time exactly. Heretofore, weight clocks had been used by scientists, but they had been very inaccurate. To serve his need, Huygens figured out how a pendulum could be attached to a clock driven by weights in such a manner that it would keep accurate time. Then he went on to work out the idea of the spring balance, which would take the place of the pendulum and make possible timepieces which would run in any position. Whenever you look at your watch for the correct time, you are indebted to this mathematician who made it possible for us all to have small, convenient timepieces. (See page 7 of this volume.)

Huygens is also remembered for his work in astronomy. With a telescope which he made himself, he discovered one of the satellites, Titan, which revolves around Saturn. Then he described accurately Saturn's ring which is shown in the picture facing page 38 of Volume I.

Still another problem interested this scientist. It had recently been discovered that light has a definite rate of traveling across the sky, and philosophers and scientists were asking the question, "What is light?" That does not seem at first thought a difficult question, but it is one that science has not yet answered to its satisfaction. The Greeks had long ago shown that sound is, in reality, a vibration or trembling of the air, which travels along until some wave strikes against the drum of our ears and causes the sensation we call "sound."

Huygens thought that light could also be explained as a vibration. But there was this difficulty: the air does not extend outside the earth as far as the sun and stars. And if light is a vibration, there must be something to vibrate. He decided, therefore, that there must be some invisible substance which fills all space, even that between the earth and the distant sun. He called this substance "ether." According to this explanation, the sun would then make vibrations or light waves in the ether which would strike against the eyes and cause the sensation we call light. This was the "undulatory theory" of light. Few scientists of that time were interested in Huygens' theory, and indeed he had not explained it very clearly.

However, about the middle of the eighteenth century his theory was taken up again and more fully developed. For that reason Huygens is sometimes compared to the Vikings who discovered North America but did not bring the importance of their discovery to the world as Columbus did. Still, he was the originator of the modern theory of light which has been taught for a great many years.

WATT

(1736–1819)

JAMES WATT was the Scottish engineer who invented the first successful steam engine. There had been steam engines before his invention, but they were little more than pumps. In repairing a model of one of these old engines, Watt discovered that a great deal of steam was being wasted. He made many improvements and at last produced a steam engine which would do man's work for him. Thus he did a great deal to advance civilization. (You will find his story on page 44 of this volume.)

BENJAMIN FRANKLIN

(1706–1790)

BENJAMIN FRANKLIN was born in Boston, though Philadelphia claims his most famous years. Born January 17, 1706, when only ten years of age he was taken from school to help his father in his business of tallow-candler and soap-boiler. In his autobiography, or story of his life, he tells us all about his early years. "I was employed," says Franklin, "in cutting wicks for the candles, attending the shop, and going of errands." Candles gave most of the light in those days. At twelve Benjamin was apprenticed to his brother James, a printer, which was fortunate, for now he could educate himself. Five years he worked for his brother, and then he determined to start out for himself and seek his fortune. He tells the story as follows:

"My friend Collins agreed with the captain of a New York sloop for my passage to that city. So I sold some of my books to raise a little money, and as we had a fair wind, in three days I found myself in New York, near three hundred miles from home, a boy of but seventeen, without the least knowledge of any person in the place, and with very little money in my pocket.

"I offered my service to the printer in the place, old Mr. William Bradford. He could give me no employment, but says he, 'my son at Philadelphia has lately lost his principal man; if you go there, I believe he may employ you.' Philadelphia was a hundred miles further; I set out, however, in a boat for Amboy, leaving my chest and things to follow me round by sea. From there I proceeded on foot, fifty miles to Burlington, where I was told I should find boats that would carry me the rest of the way to Philadelphia.

"It rained very hard all day. I was thoroughly soaked, and by noon a good deal tired; so I stopped at a poor inn, where I stayed all night, beginning now to wish that I had never left home. I cut so miserable a figure, too, that I found by the questions asked me, I was suspected to be some runaway servant, and in danger of being taken up on that suspicion. However, I proceeded the next day and got in the evening to Burlington.

"Walking there by the side of the river a boat came by, which I found was going towards Philadelphia. They took me in, and, as there was no wind, we rowed all the way. We arrived at Philadelphia about nine o'clock on Sunday morning, and landed at the Market Street wharf.

"I have been the more particular in this description of my journey to Philadelphia, and shall be so of my first entry into that city, that you may in your mind compare such unlikely beginnings with the figure I have since made there. I was in my working dress, my best clothes being to come round by sea. I was dirty from my journey; my pockets were stuffed out with shirts and stockings, and I knew no soul, or where to look for lodging.

"I was fatigued with traveling, rowing, and want of rest; I was very hungry; and my whole stock of cash consisted of a Dutch dollar, and about a shilling in copper.

"I walked up a street, gazing about, till, near the market-house, I met a boy with bread.

"I had made many a meal on bread, and, inquiring where he had bought it, I went immediately to the baker's he directed me to, in Second Street, and asked for a biscuit, intending such as we had in Boston; but they, it seems, were not made in Philadelphia.

"Then I asked for a threepenny loaf, and was told they had none such. So, not knowing the difference of money, or the greater cheapness or the names of his bread, I bade him give me threepenny-worth of any sort.

"He gave me, accordingly, three great, puffy rolls. I was surprised at the quantity, but took it, and, having no room in my pockets, walked off with a roll under each arm, and eating the other.

"Thus I went up Market Street as far as Fourth Street, passing by the door of Mr. Reed, my future wife's father; when she, standing at the door, saw me, and thought I made, as I certainly did, a most awkward and ridiculous appearance.

"I then turned and went down Chestnut Street, and part of Walnut Street, eating my roll all the way. Coming round, I found myself again at Market Street wharf, near the boat I came in, to which I went for a draught of the river water; and being filled with one of my rolls, I gave the other two to a woman and her child who came down the river in the boat with us, and were waiting to go farther.

"Thus refreshed, I walked again up the street, which by this time had many clean-dressed people in it who were all walking the same way. I joined them, and thereby was led into a great meeting-house of the Quakers, near the market.

"I sat down among them, and, after looking round awhile and hearing nothing said, being very drowsy through labor and want of rest the preceding night, I fell fast asleep, and continued so till the meeting broke up, when one was kind enough to rouse me. This was, therefore, the first house I was in, or slept in, in Philadelphia."

This was the humble beginning of the man who made the first discoveries in electricity by means of his famous kite with a small thread which could bring down the lightning; who invented the Franklin stove, or "Pennsylvania fireplace"; who originated "Poor Richard's Almanac," which became almost as familiar in the household as the Bible; who was one of the foremost philosophers and statesmen of his day, and one of the truest patriots. (You will read about his service as a statesman and will find his picture in Volume VII, pages 198 and 199.) Among other important facts that we should remember about Franklin are that he started the Philadelphia library and founded the American Philosophical Society and the University of Pennsylvania.

We have seen his awkward entrance into Philadelphia; but years later, when he went to England and France to represent his country, he delighted all by his wit and knowledge and courteous manners. It was largely due to him that France made a treaty with the colonies, which meant that the French would fight with the Americans against the English. Franklin never forgot that he was an American, and the country owed very much to him in the early and trying days. When he died, at the age of eighty-two, April 17, 1790, twenty thousand of his countrymen met to do him honor, and in English and French courts remarkable tributes were paid to him. A great throng of people followed his body to Christ Church cemetery, in Philadelphia, where it rests.

LAMARCK

(1744–1829)

JEAN LAMARCK, French naturalist, gave many new and interesting ideas about the way in which animals might change and develop. (You will find his story in Volume I, page 266.)

HUMBOLDT

(1769–1859)

ALEXANDER VON HUMBOLDT was the German naturalist who collected much of the information which makes geography interesting. (You will find his story in Volume I, page 271.)

DALTON

(1766–1844)

JOHN DALTON has been called the "lawgiver of chemical science." (You will find his story in Volume I, page 269.)

FARADAY

(1791–1867)

THE story of Michael Faraday is the story of a poor English boy who thought that chemistry and electricity were the most fascinating things in the world. When he was only thirteen, he was apprenticed to a bookbinder, and there seemed no possible chance of his ever becoming a scientist. However, he worked out many simple experiments in chemistry by himself and constructed an electrical machine. Sometimes, too, he could manage to attend scientific lectures.

The most exciting lectures that he attended were those given by the great English chemist, Sir Humphry Davy. After listening to Davy, the young man felt that he could not bear the work in the bookbinder's shop, and he wrote to Davy, sending the notes which he had taken on the lectures, and asking for any employment connected with science.

It is said that Davy asked a friend what could be done about the young man who had asked so boldly for a position. The friend answered, "Put him to wash bottles: if he is good for anything, he will do it directly; if he refuses, he is good for nothing." But Davy replied, "No, no, we must try him with something better than that." And try him they did. Not long after, Faraday became an assistant to the great Davy himself. This gave the youth an opportunity to study, experiment, and also to show what he could do.

Faraday's greatest work was in the world of electricity, for he discovered the law of the dynamo. (You will find this very important law explained on page 68.) On the day when this discovery was made, he was so happy that he danced about the laboratory and then suggested to his assistant that they go off to celebrate. Accordingly, the two of them dropped work for the day and went to Astley's to see the horse races. (He may be seen in the group on page 377 of this volume. You will also read a fuller story of him in "Lives Worth Knowing" in Volume VIII.)

CARNOT

(1796–1832)

NICHOLAS LEONARD SADI-CARNOT was a French physicist who gave the first correct explanation of the part heat played in mechanical action. Up to the beginning of the nineteenth century, heat was thought to be a separate something which dwelt in anything that could be burned and was called "caloric."

Carnot constructed what he called a "reversible" engine, where the amount of heat (caloric) applied and the amount of motive power (energy) obtained could be watched and studied. His observations were published under the title, "Thoughts Upon the Motive Power of Fire and the Proper Machine for Utilizing its Power." This work showed him to be one of the world's most original thinkers. It is said that the science of thermodynamics — which is the study of the relations between heat and mechanical action — was born with his investigations. He died of cholera when he was only thirty-six years old, before he understood how extremely important his work was to be in the development of engines. (He may be seen in the group on page 379 of this volume.)

JOULE

(1818–1889)

JAMES PRESCOTT JOULE, the English physicist, was born in Salford, near Manchester. Like many boys, he was very much interested in electricity. When he was only nineteen, he published an article describing an electromagnetic engine which he had invented himself.

From this beginning, he went deeper and deeper into the study of electricity and physics. He wanted particularly to discover how much work, or mechanical energy, was required to produce a certain amount of heat. This, you see, was approaching the subject from a different point of view from Carnot. By means of a series of famous experiments, carried on over a period of forty years, Joule was finally able to "balance" the exact relation between mechanical energy (work) and heat in formulas or equations that will stand for all time. These laws governing heat and mechanical energy led him to discover the more general law of the conservation of energy. Nothing in the universe, no substance, no force was lost. If energy seemed to disappear, it was actually being saved or conserved, though changed into some other form or appearance.

Because of these studies, the practical unit of energy used by physicists to-day is named for Joule. Each time they measure energy in terms of "joules" they are paying tribute to this pioneer of the nineteenth century.

His investigations also led him to point out the value of surface condensation in increasing the efficiency of the steam engine. Thus, one of the most important improvements in the steam engine was made possible. (He may be seen in the group on page 379 of this volume.)

HELMHOLTZ

(1821–1894)

HERMANN VON HELMHOLTZ, the German physicist, was one of the greatest scientists of the nineteenth century. In 1893, when he was elected honorary president of the International Congress of Electricians held at Chicago, it was said that he could have been chosen as a leader in several other fields of knowledge. We are indebted to him for the invention of an instrument with which oculists examine the inside of the eye and for an explanation of the bones in the ear.

He is placed with Joule as one of the founders of the law of the conservation of energy. You remember that energy cannot be destroyed or lost. It is, in fact, waiting all about us. As Helmholtz points out in a famous essay on the subject: "We cannot create mechanical force, but we may help ourselves from the storehouse of nature. The brook, the wind, which drive our mills, the forest, the coal-bed, which supply our steam engines and warm our rooms, are the bearers to us of the small portion of the great natural supply which we draw upon for our purposes." (Helmholtz may be seen in the group on page 377 of this volume.)

MAXWELL

(1831–1879)

JAMES CLERK-MAXWELL seems to have been a born scientist. When he was fifteen his first scientific paper was considered so important that it was read before a society of scientists by one of the professors of the Edinburgh Academy where the boy was then going to school. Two other papers were published by this society when he was only eighteen.

Maxwell was born in Edinburgh. After studying at the Academy and the University there, he went to Cambridge. In the English University, he showed unusual ability in mathematics, physics, chemistry, and philosophy. Later, when a new department of experimental physics was opened, he was asked to take charge of it.

Much of his work is too scientific to explain here. It is considered that his most important work is in the field of electricity. He followed the experiments of Faraday, but connected and arranged them so that the material could be used for mathematical discussion and treatment. He showed that electromagnetic action travels through space in the form of transverse waves like those of light and that both sets of waves have the same speed of travel. Therefore, he said, electricity and light are the same in their ultimate nature. This theory of electromagnetic waves provided an important step in the development of radio communication.

Next in importance, after his research in electricity, comes his work on color. He proved that any single color can be produced by the combination of the three primary colors. These three fundamental colors would correspond to three different sets of nerves or sensations in the eye. If any one set was absent in an individual, he would be color-blind. The Maxwell disk and color box for testing eyesight were his invention. These are exceedingly simple, but it often takes a great deal of knowledge and ingenuity to work out the simplest truths.

Maxwell died when he was only forty-eight, but he had already shown himself to be the leading physicist and mathematician of his day, and one of the greatest of all time. (He may be seen in the group on page 379 of this volume.)

GIBBS

(1839–1903)

JOSIAH WILLARD GIBBS was the most distinguished American mathematical physicist of the nineteenth century. For more than thirty years he was a professor of physics at Yale College. His studies and investigations are too technical to explain here. The truths he discovered, however, have helped inventors to work out problems of constructing and operating complicated machinery. They also solved certain difficult problems dealing with the computation of the orbits of planets and comets. Thus, Josiah Gibbs gave a better understanding of that very great mechanism — the Universe. Most of his life he worked so modestly and quietly in his laboratory that few people knew he was making remarkable discoveries. European scientists were the first to recognize his genius. Now scientists everywhere pay high tribute to him. It is said that he created the "immense domain of chemical mechanics," and that this creation was so complete and perfect as it came from his hands that little or nothing has ever been added to it. (He may be seen in the group on page 377 of this volume.)

Keystone

JAMES WATT PLAYING WITH STEAM

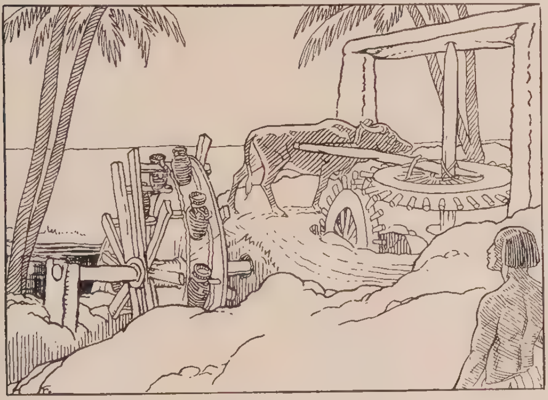
POWER

PRIMITIVE man, apparently condemned to the slavery of incessant labor with his hands, took his first step toward freedom when he applied the muscular power of domestic animals to performing his daily tasks. Before this, his own muscles had been his sole source of energy. "Power," as we call it, is only another name for energy that can be controlled and applied to mechanical work. Power has many sources. It may come from the work of men or of animals, from falling water, from the rise and fall of ocean tides, from the heat of burning fuel.

It will probably never be known to whose superior intelligence it first occurred that the energy of wind and water might furnish further relief from toil. It may have been from the damage wrought by a swollen stream, or from the tug of the wind at his hair, that some man gained the first hints that here in nature were powerful forces awaiting his use.

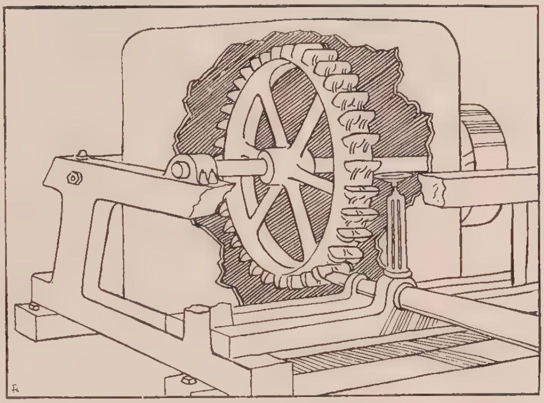
POWER FROM WATER

The Chinese were among the earliest known users of water power. To lift water for the irrigation of their fields they employed water wheels made of buckets and bamboo poles.



AN EARLY WATER WHEEL

The principle of the water wheel such as is still seen in many an old grist-mill was made use of as early as 70 B. C. These early wheels were made by fastening a few boards or vanes to the end of a millstone spindle. They were moved by the impact of a stream of running water, thus furnishing the power to turn the millstone. These "current" water wheels, with flat paddles dipping into a moving stream, were used in China, Egypt, and Assyria many centuries ago, and were also known to the ancient Greeks. A large wheel of this type pumped the water supply for London about 1581.

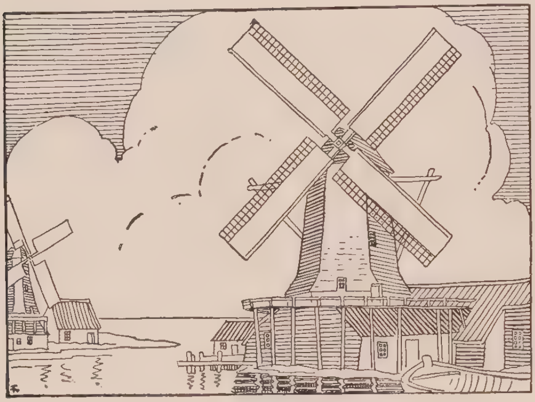


THE PELTON WHEEL

We have heard in recent years of projects for the development of great quantities of power by utilizing the rise and fall of the huge tides that occur in places such as the Bay of Fundy. Mills operating on this tidal principle were known in Venice as early as 1046.

Of course the power of these early wheels was small. The largest industrial water wheels up to the end of the eighteenth century did not exceed ten horse power in capacity. These primitive mechanisms gradually gave place to the modern water turbine, which is very efficient and has been built in units as large as one hundred thousand horse power. The principle of this turbine was first successfully employed by Fourneyron, a Frenchman, in 1827. It came into commercial use about 1850. In the modern turbine, stationary guides direct the flowing water into the rotating wheel, a method similar to that followed in the steam turbine which is described on page 52 of this volume.

Another kind of water wheel, known as the "impulse" type or Pelton wheel, has bucket-shaped blades or vanes set at regular intervals about its rim. A stream of water, coming at high pressure from a nozzle, is directed against the buckets at the bottom of the wheel. The impact of this swiftly moving jet of water on the blades causes the wheel to revolve at high speed.



A DUTCH WINDMILL

If you should drop a weight of fifty pounds or more from the top of a twenty-story building, you can imagine the tremendous impact with which it would land. A cubic foot of water weighs about sixty-two and one-half pounds. Picture to yourself millions of these heavy cubic feet of water tumbling to the bottom of a great waterfall, and you may be able to envision the truly huge amount of energy that the falling water possesses. With this picture still in mind, you will not wonder at the statement that if all the energy of Niagara Falls could be used, this cataract alone could furnish enough power to light the entire world with electricity.

The discovery that by the aid of the electric dynamo the power generated by a water turbine could be transferred over long distances bids fair to make this form of power one of the most important factors in the doing of the world's work.

POWER FROM THE WIND

The application of sails to boats formed one of the earliest uses of the energy exerted by moving air. Sailing ships, driven by uncertain winds, are gradually disappearing before the steady sources of power such as the steam and internal-combustion engines. In fact, wind power is no longer reckoned important among the motive powers of the world.

Another familiar example of the use of wind in generating or producing power is the windmill, which dates back to the twelfth century. It is still to be found in agricultural districts, in spite of all the developments of steam, electrical, and gasoline power. The windmill goes only when the wind blows, and hence cannot be depended upon where a steady supply of power is necessary. Its cheapness will continue to keep it in use for certain purposes, such as pumping water. Were it not for the windmill, a country like Holland would not only lose its picturesqueness, but might suffer tremendous harm from invasions of the sea. On Cape Cod, in Massachusetts, old windmills still stand which in earlier years ground the grain of many a small community.

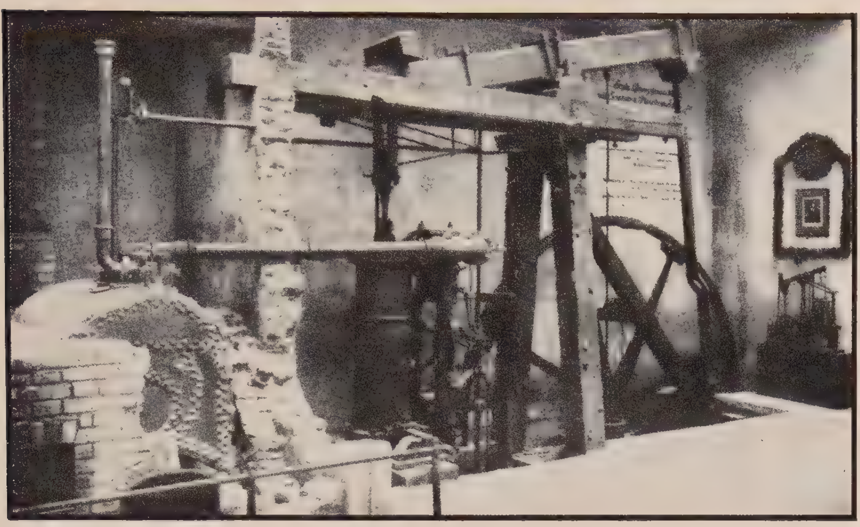
In its simplest form, a windmill is a series of inclined planes forming the spokes of a wheel. The impact of the wind turns this wheel, which delivers its power through gearing and a long shaft to the pump, grinder, or other mechanism which it may operate.

OTHER SOURCES OF POWER

The chapters on steam, electricity, and the internal-combustion engine will give you a brief view of the development of these important sources of power. We may here also mention that a heat engine, or "cannon," was used at the end of the thirteenth century, preceding the steam engines of Watt and Newcomen. An internal-combustion engine, using coal gas as a fuel, was built in 1860 by a Frenchman named Lenoir.

A FARM WINDMILL

The development of power made possible the age of machinery, which delivered man from the bondage of ceaseless toil.



JAMES WATT'S STEAM ENGINE
The invention that made the Machine Age possible.

STEAM

UNTIL the year 1700 A.D., man's quest for power to operate his few crude machines had been satisfied with the waterwheel, the windmill, and the labor of such animals as he could harness to work for him. From these and from his own sturdy muscles came the energy that turned the wheels of the world's simple industries.

Yet, through centuries of toil, there had been within man's hands the giant Steam, merely awaiting the touch of the inventor's magic wand to enchain his wasted energy and transform it into useful work. This was the force that lifted mankind from an era of backbreaking slavery into the freedom of the Age of Machinery.

For hundreds of years, scholars had watched with interested eyes the action of water under the influence of heat. They saw that when boiling, it gave off a vapor (which we call "steam"). They also discovered that this vapor possessed a tremendous power of expansion. We know to-day that a little water makes a lot of steam, for the steam occupies 1600 times as much space as the water from which it came.

More than one hundred years before Christ, Hero of Alexandria, in Egypt, recognized the force contained in this power of expansion, and employed it in making a sort of engine which rotated itself by blowing jets of steam into the air. In 1630, a French writer described a method of raising water to the upper part of a house by means of steam, and a similar plan was set forth by the Marquis of Worcester in a book published twenty-five years later. Yet nearly fifty years more went by before steam was put to really practical use.

It is strange that coal, now so much a partner of steam in producing power, should have been responsible for the first invention in the series that led to the development of the steam engine. In England coal had been dug for many years. As the mines grew deeper, water entered them and pumps were needed to keep them dry so that the supply of fuel would be uninterrupted. Hand power and horse power, applied to crude pumps, were unable to keep back the rising waters, and mine after mine had to be abandoned. To save her supply of fuel, England needed a pump that could draw water as fast as it rose.

Denis Papin, a Frenchman, was the first to see this opportunity, but his genius was unable to carry his ideas to a successful conclusion. Yet Papin's early experiments with steam led to the invention of the first practical steam pump by Thomas Savery, an English military engineer, in 1698. This pump was far from perfect, and met with little favor among the mine-owners. Shortly afterward, Thomas Newcomen produced a much improved pump, which was successful from the time it was first set to work in 1711. Savery and Newcomen became partners, and it was not long before their engines were to be found in nearly every mine in England. Crude as this engine was, it was a triumph of human ingenuity, and its use restored the fortunes of dozens of owners of flooded mines.

While the steam pump, the locomotive, and the steamboat preceded the use of steam power in manufacturing, it is nevertheless true that James Watt's invention of the steam engine opened the door to the Age of Machinery. It was this ingenious Scotch boy who turned Hero's toy into a useful engine and made possible the freeing of the slave and the enrichment of the world.

THE INVENTOR OF THE STEAM ENGINE

Born in Greenock, Scotland, on January 19, 1736, James Watt was so feeble a boy that he was unable to attend school regularly like other children. Much of the time found him confined to his room, where lessons in reading, writing and arithmetic were given him by his father and mother.

Even without the advantages of the schoolroom, the brilliant mind of the boy was early to be seen. "Why do you let the boy waste his time so?" a neighbor said to Mr. Watt when he found the child stretched on the floor and drawing lines upon it with chalk. "Why don't you send him to school where he will learn something useful?" "You may find, sir, that you are mistaken," Mr. Watt replied. "Examine for yourself and see what my son is about." It was a problem in geometry that was occupying this six-year-old boy.

Six years later, the lad sat one day at the tea table with his aunt, Mrs. Muirhead. His apparent idleness exasperated her and she spoke sharply. "James Watt, I never saw such an idle boy. Take a book and employ yourself usefully. For the last hour you have not spoken one word, but have taken off the lid of that kettle and put it on again, or held a cup or a spoon over the steam at the spout. Are n't you ashamed of spending your time in this way?" Even then the young genius was thinking of the power and possibilities of steam.

The mechanical talent of young James had been encouraged by his father by the gift of a set of tools, with which he took apart and put together all his toys and made many new ones. A small electrical machine of his manufacture gave forth brilliant sparks to the amusement and astonishment of the neighbors.

Often confined at home by illness, the boy devoted himself to the study of chemistry and physics. At the age of nineteen he journeyed to London and worked for a year under an expert maker of mathematical and nautical instruments. The skill gained in this delicate work must have played a large part in his later success.

In Glasgow at this time the trades were strictly organized under guilds. When Watt returned there from London, with the intention of opening a small shop of his own, the guilds prevented him because he had not served the full term required of an apprentice. The University of Glasgow came to his aid and allowed him the use of one of its rooms, also giving him employment in caring for its scientific apparatus under the title of instrument-maker to the university. This was a happy connection for Watt, then not quite twenty-one years old, for it brought him into close touch with some of the finest scientists of his day and made them his friends as well as his patrons.

A model of the Newcomen engine was in a laboratory of the university, and it was one day brought to Watt for repair. Like any good workman, he soon had the model again in working order. But Watt went further. He began to think. When he tested the repaired engine, he was surprised to find that the water in the boiler disappeared in a few minutes. Steam seemed to be used up faster than the boiler could supply it.

Watt's mind soon found the difficulty. He discovered that the cylinder cooled between strokes, and that so much steam was condensed in warming up the cylinder that very little steam was left to operate the pump. By keeping the cylinder hot, he thought, we can prevent this waste of steam. Several days of pondering on a means of doing this brought no answer to the problem. At last the idea came. Why not make a separate condenser outside the cylinder, and connect the two with a short pipe? His model, built on this principle, was successful. Some say the separate condenser was Watt's greatest contribution to the steam engine.

Watt made improvement after improvement, until in 1769 he took out patents on a machine which was the first real steam engine. It had become a source of power instead of merely a pump. No other man in history has done so much to advance civilization.

Fifteen years later, Robert Fulton's little steamboat made its trial trip on the River Seine in France. Within twenty years Fulton used a Watt engine in running the *Clermont* from Albany to New York in thirty-six hours.

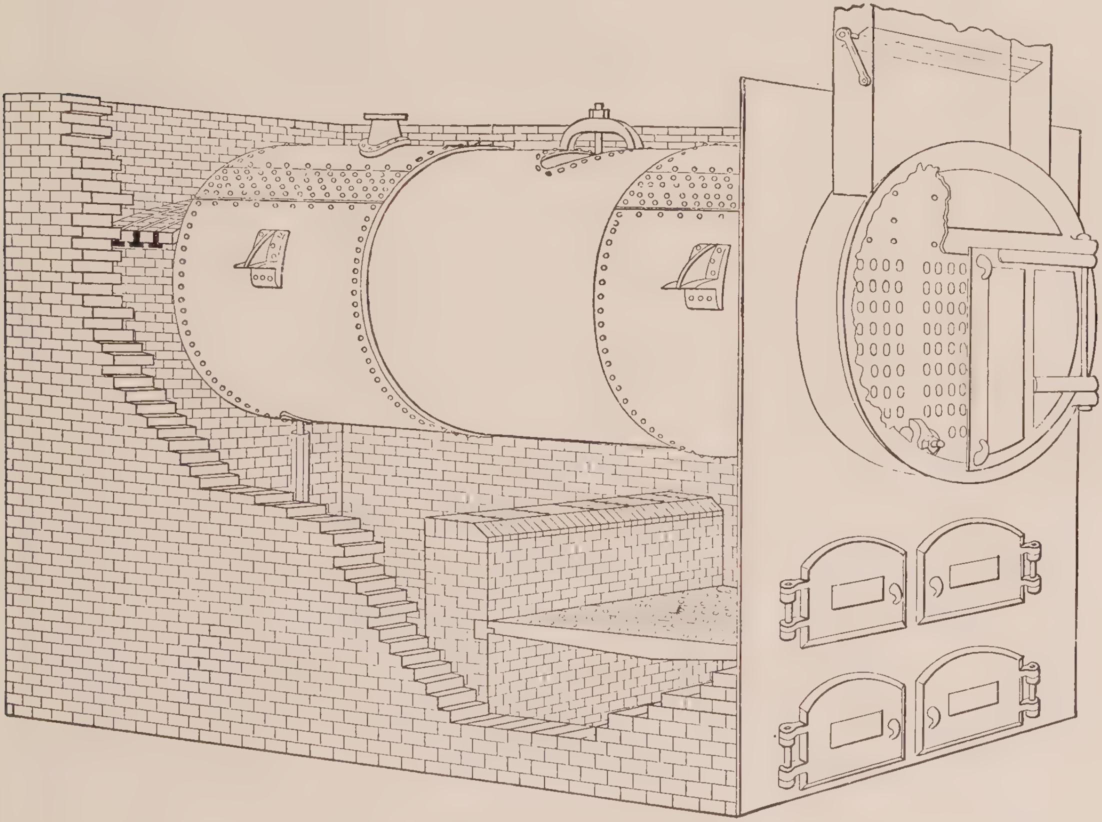
The world was ready for this great invention, and James Watt was the man with the skill and and genius and industry to perfect it. The man and occasion were at hand. That is the secret of all great accomplishment.

HOW DOES THE STEAM ENGINE WORK?

When steam is confined in a cylinder and a piston is pushed down against it, it will push back at the piston with great force. The early engines of Watt employed this simple principle. The same inventor soon produced a double-acting cylinder. In this, steam was admitted to drive the piston to one end of the cylinder, and the expanded steam was allowed to escape. Then steam was let in behind the opposite side of the piston and pushed it back to its first position.

Thus we see that if steam is admitted through small openings or ports, first into one end of the cylinder and then into the other, this steam will drive the piston back and forth as long as the pressure is maintained. This is the principle of what is called the reciprocating engine.

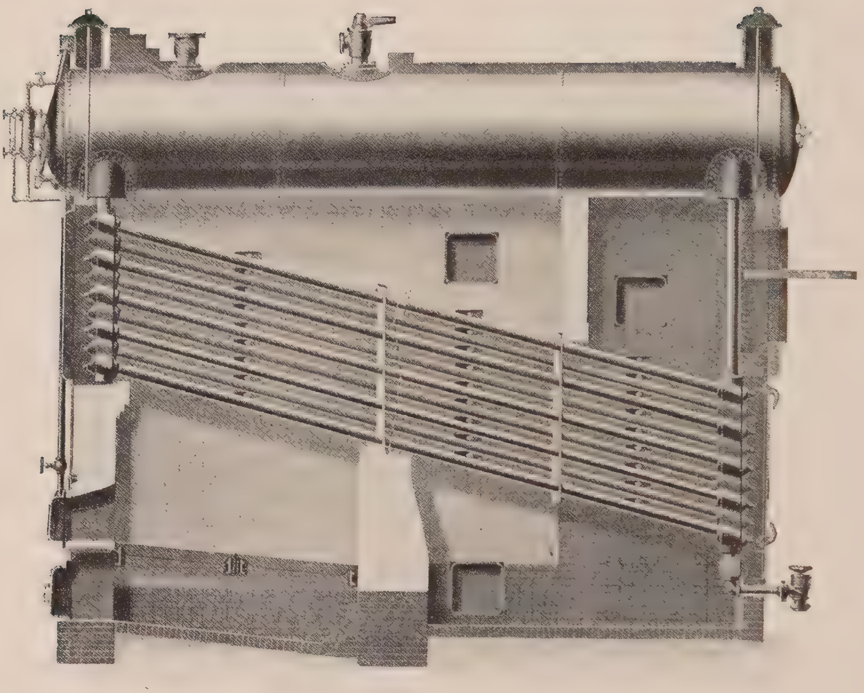
We already know that by confining water in



From "Steam-Boilers," by courtesy of Edward F. Miller

A FIRE-TUBE BOILER

The hot gases pass through tubes in this boiler before going out the chimney



A WATER-TUBE BOILER

The advantage in this boiler lies in the fact that higher pressures may be used than in fire-tube boilers and that it makes steam more quickly.

a boiler and changing it to steam, we are able to produce high pressures, the average working pressure in a boiler being about 125 pounds to the square inch. So steam engine operations begin in a boiler.

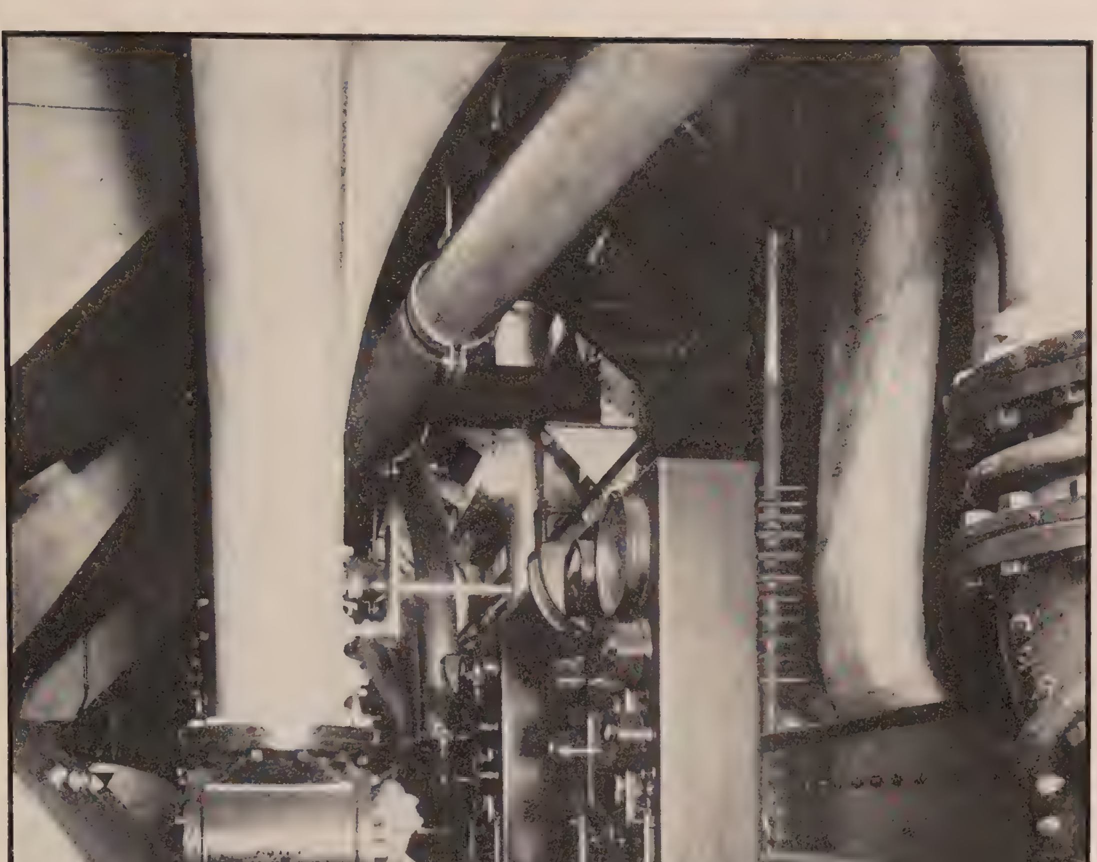
The first boilers were simply kettles having the lid fastened on tight and with a pipe to take the steam to the engine cylinder. Such boilers, however, were slow to heat, and tubular boilers were constructed. These had many tubes passing through the water space, dividing it up and allowing the heat passing through the tubes to come in contact with a larger surface of water, thus heating it more quickly.

The most powerful locomotives to-day have boilers containing many tubes, which with the fire box give more than ten thousand square feet of surface for the heat to act upon. The illustrations show how the parts are arranged in several kinds of boilers.

The vertical boiler, such as is used with a donkey engine where buildings are being erected, has upright, or vertical, fire tubes. The furnace is surrounded by water, and coal is fed through a door on the side.

On page 45 is shown a horizontal fire-tube boiler in its setting of brickwork. The fire is built on the grate under the boiler. The hot gases pass over the wall at the back of the grate, then enter the fire tubes at the rear and move forward to the front end, where they pass through the flue to the chimney. This type of boiler is much used for pressures below 150 pounds and where the amount of steam taken from the boiler does not vary, as in mills and factories.

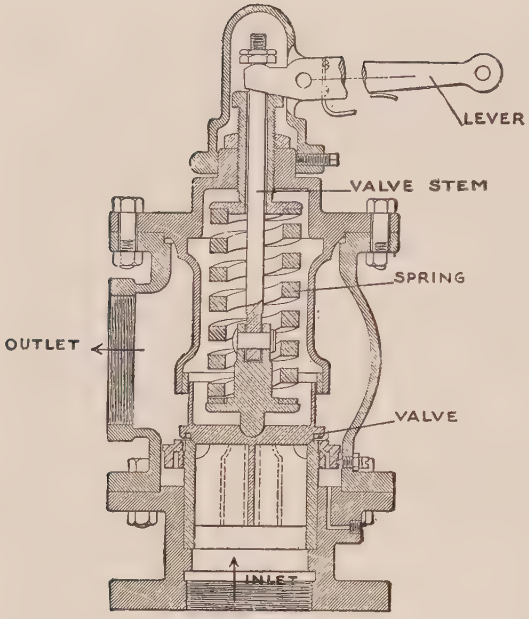
Above is a water-tube boiler. These boilers are not so dangerous as the one just described, as most of the water is confined in small tubes. If one of these should give way, there would be no very serious damage. For this same reason, higher pressures may be used, the greatest seldom being above 250 pounds to the square inch. The water circulation in this kind of boiler is much better than in fire-tube boilers, and they will, therefore, make steam much more quickly.



Ewing Galloway

IN A MODERN BOILER ROOM

Old methods of feeding fires by hand have been largely done away with by the modern mechanical stokers. This fireman is seen operating a device that automatically supplies the fires with pulverized coal. Oil is also used as fuel in many boiler rooms.



From "Steam-Boilers," by courtesy of Edward F. Miller

THE SAFETY VALVE

When the pressure in a boiler rises nearly to the danger point, the valve is forced open and steam escapes.

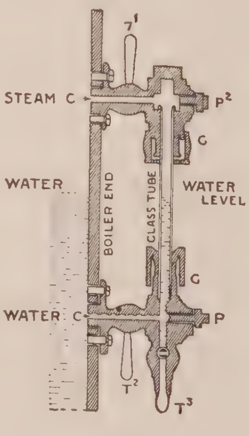
If we take bellows and send air rushing up through an open fire, it will burn much more rapidly. If a similar thing is done with the fire of a steam boiler, it is called "forced draft." The fires beneath the boilers are so arranged that air under pressure is forced up through them and has no other way to escape than by passing through to the chimney. This makes the combustion very rapid and greatly increases the heat and the resultant amount of steam. Forced draft is used on naval vessels and other fast boats. It is also used in many stationary power plants. Oftentimes by using forced draft a cheaper grade of coal may be burned and much money saved.

The most important fittings on a boiler are the safety valve, the water gauge, the steam gauge, and the mechanism for feeding the boiler with water.

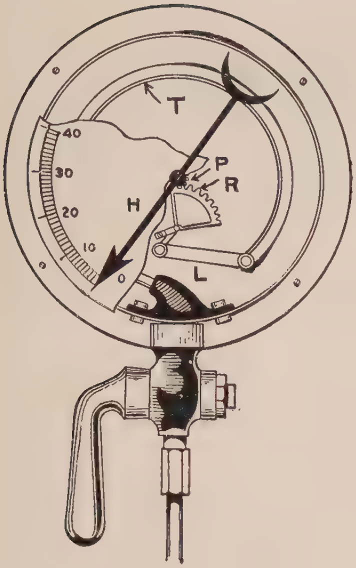
Steam is a good servant but a terrible master, and must always be kept under control. If the steam pressure within a boiler becomes too great, it must either be allowed to escape or the boiler will burst, with terribly disastrous results. Steam thus confined is as dangerous as gunpowder. Hence every boiler has a safety valve. This is a valve or cover which fits tightly over an opening in the top of a boiler where the steam is stored. This cover is held in place by a heavy spiral spring which may be so regulated that the valve will open at any desired pressure. This pressure is usually five or ten pounds above the working pressure, but well below the danger point. The safety valve must open wide enough to discharge all the steam that the boiler is capable of making. It remains open until the pressure drops three or four pounds below the blowing point and then closes suddenly. After a safety valve is set to blow at the proper pressure, it is locked, usually by the boiler insurance company, so that it cannot be tampered with. By means of a lever on the top, the valve may be opened by hand. This is done at least once a day, to be sure that the valve is not sticking on the seat. Such a valve is shown here, with the various parts indicated.

The water gauge, or water column as it is usually called, consists of an upright glass tube so connected at each end with the boiler that the level of the water therein will be shown in the tube. This tube must, of course, be able to stand the same steam pressure as that in the boiler, and is therefore made of very heavy special glass.

The steam gauge shows in a different way the amount of steam pressure at any given time, an arrow registering it on a dial, as may be seen in the accompanying illustration. Pressure within an elastic tube always tends to straighten it. So such a tube, bent within the dial, straightens with the pressure and swings the arrow a distance proportional to the pressure. The safety valve works automatically and does not need the attention of the fireman; the steam gauge and water column, however, require constant watching to keep the boiler working within its safe limits of steam pressure and water level.



A WATER GAUGE



THE STEAM GAUGE

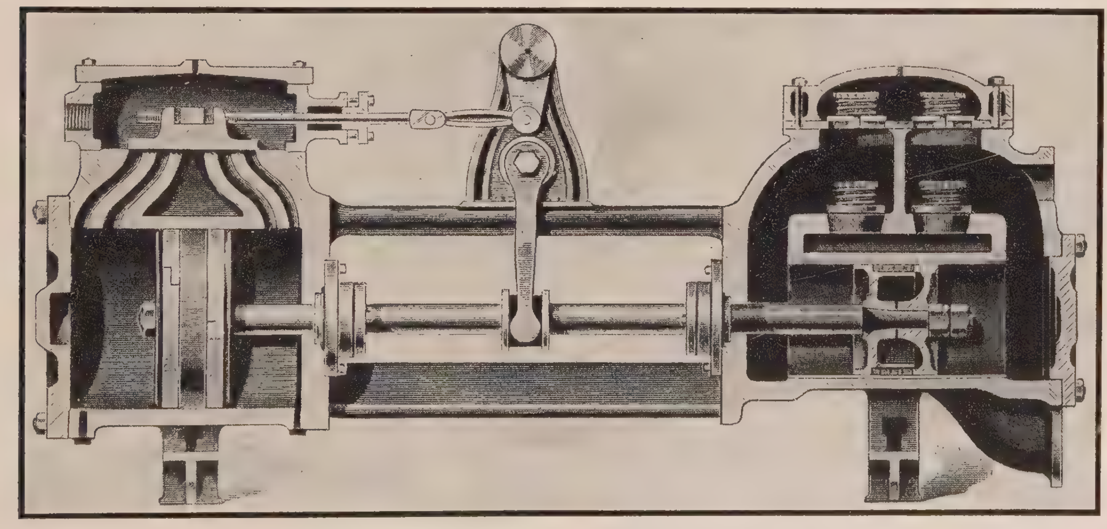
When a boiler is supplying steam for any purpose, an amount of water equal to the steam used must be pumped into the boiler to keep the water level at the proper height. This is generally done by a boiler feed pump, of which there are many types. Some are driven by steam, some by electric motors, and others, in small plants, by power from the main engine. The diagram shows the principal parts of a steam-driven pump. At the left is the steam cylinder with its piston and its valve for admitting and discharging the steam. At the right is the water cylinder, with its plunger, or piston, attached to the same shaft as the steam piston. The pump valves, four of which are shown, are rubber disks held in place by springs. The two lower are the suction valves; the two upper are the discharge valves. Both cylinders are double-acting; that is, they do work at both ends.

You will notice that this feed pump has no flywheel because it is often necessary to run it much more slowly than would be possible if a flywheel were used. As there is no flywheel to steady the action of the pump, a great deal of steam must be used to make it run properly.

Thus we have within the boiler the giant Steam, pushing with all his might to get out, and eager to rush through any valves or pipes to make his escape. The steam engine converts this energy into action, forcing the giant to push the piston back and forth on his way to freedom.

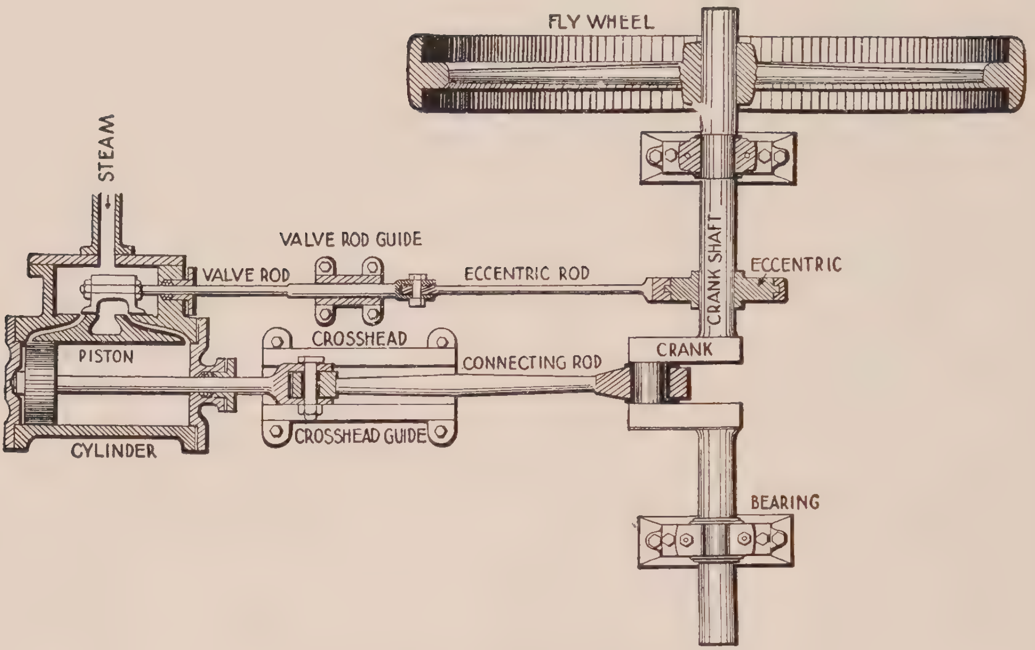
There are two types of steam engine. First comes the reciprocating engine, which is the sort of which Watt dreamed as he watched the lid of the tea kettle dance. This engine uses a piston and cylinder, and turns a flywheel by means of a connecting rod and a crank. It is the kind of engine most commonly used to-day. The other type is the rotary or turbine engine, of which we shall speak further along in our story.

On the next page is shown a simplified diagram of a reciprocating engine. Steam from the boiler enters the valve chest in which the valve is moving back and forth. The valve admits the steam



A DIRECT-ACTING STEAM PUMP FOR FEEDING BOILERS

At the left is the steam cylinder with its piston, at the right the water cylinder and its plunger.



PRINCIPAL PARTS OF A SIMPLE STEAM ENGINE

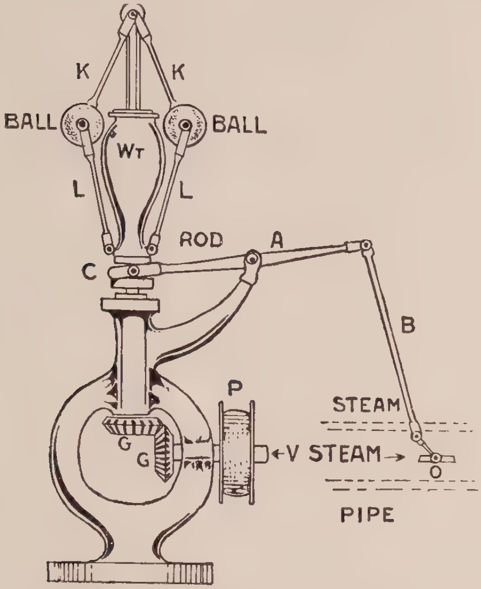
first to one end of the cylinder and then to the other. At the same time it opens a way to the exhaust pipe, so that the used steam may pass out of the cylinder after it has done its work. The movement of the piston is carried by the piston rod to the crosshead, which slides to and fro on its guides. This sliding motion operates the connecting rod which turns the crank. This is fastened to the crank shaft, which turns the flywheel from which the useful work of the engine is obtained. The shaft and flywheel are supported by two bearings. On the shaft is a device called the eccentric. This is similar to a crank in its action, and produces a slight sliding motion which is carried through the eccentric rod and the valve rod and moves the valve back and forth. The stuffing box at the end of the cylinder is packed with material which prevents steam from escaping and yet allows the piston to slide freely back and forth.

THE GOVERNOR

The work which many engines do is continually varying in quantity. For instance, with an engine driving a machine shop, the different machines are constantly starting and stopping. so that at one moment fifty horse power may be needed and a moment later only forty horse power. Now the speed of the engine must be controlled, no matter how much the work varies. The governor is what makes this possible, and all except small, unimportant engines are equipped with one.

Governing is usually done in one or the other of two ways. Either the pressure and quantity of the steam are varied, or the pressure is kept constant and the quantity alone is changed. An example of the first type, which is called the "throttling" governor, is shown in the illustration. This consists of a vertical shaft on which hang two heavy balls connected to a weight by links. From the bottom of the weight, rods lead to a sort of shutter or valve in the steam pipe.

The shaft is turned by a belt from the main shaft of the engine. As this governor shaft revolves, the balls spin around it and are thrown outward by centrifugal force. As they fly outward, they lift the weight, and through it operate the rods and close the steam valve. As a result, the steam is "throttled" more and more as the speed increases. When the steam has been so cut down that the engine speed decreases, the balls fall and the valve opens again.



THE "THROTTLING" GOVERNOR, INVENTED BY WATT

Now used only on small engines.

This form of governor was another of James Watt's inventions. It is now used only on small engines, as it causes the engine to run with poor economy. Governors which vary the quantity of steam without changing the pressure are called "flywheel" governors, as they are usually attached to this part of the engine. They are a combination of weights and springs, the weights assuming different positions for different engine speeds. The valve of the engine moves as the weights move, thus varying the quantity of steam used.

THE CONDENSER

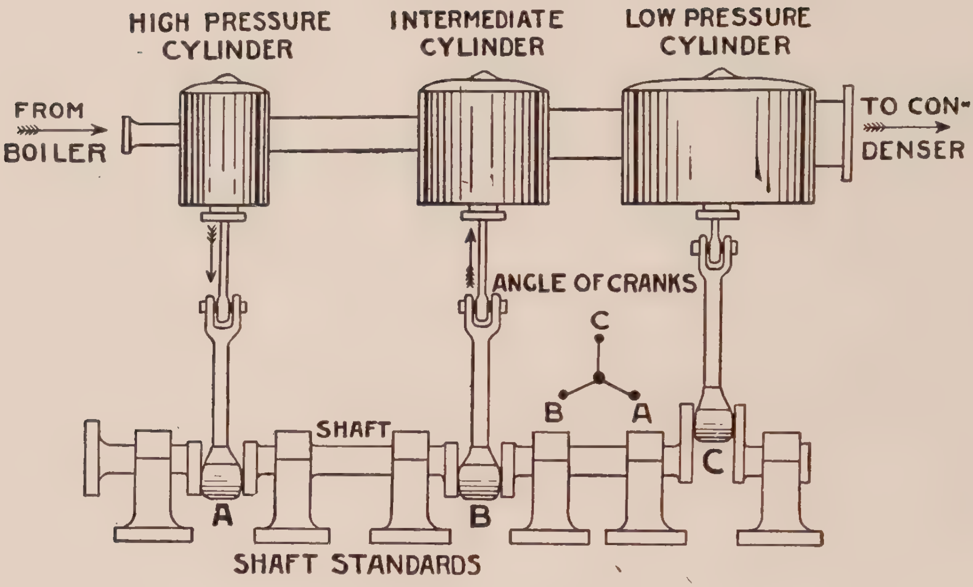
When steam is exhausted from an engine into the atmosphere, it is thrown away. Now in many places, as on board ship, the supply of water which may be used in the boilers is limited, and none of it must be wasted. In such cases the steam leaving the engines, instead of passing uselessly into the air, is directed into a receptacle called a "condenser," where it is changed back to water, so that it may be used again in the boiler. Condensers where the steam and the cooling water are mixed together are called "jet" condensers. Where the exhaust steam and the cooling water are kept separate by having the water pass through tubes and the steam circulate within a closed shell around these tubes, the condenser is called a "surface" condenser. These latter are used on shipboard, where salt water may be used for cooling the steam which is made from fresh water.

Besides saving the condensed steam for further use, the pump which pumps the condensed steam from the condenser, in so doing causes the pressure against which the engine is exhausting to be lowered considerably. This adds to the power and economy of the engine. The condenser was invented by James Watt.

COMPOUND ENGINES

In the early days of the steam engine, the pressures used were low, not generally over fifty pounds. A single cylinder was all that was necessary to get as much work as was possible at such pressures. As the pressures increased, however, it was seen that much more work could be obtained from the same steam if the expansion were divided between two cylinders instead of all taking place in one. A compound engine was therefore designed with two cylinders, one called the "high-pressure" cylinder and the other the "low-pressure" cylinder, and the work was divided between the two. Steam from the boiler entered the high-pressure cylinder at a steam pressure which was usually from 125 to 150 pounds, and by expanding somewhat, changed a part of the heat energy of the steam into work. Leaving this cylinder at a pressure of from twenty to forty pounds, the steam passed into the low-pressure cylinder, which was made much larger than the other, owing to the greater volume of the steam at low pressures, and there finished its expansion. It was finally exhausted from this cylinder at a very low pressure.

Later it was found that better economy could be obtained with large engines by dividing the expansion among three cylinders, and thus the triple-expansion engine appeared. The general



TRIPLE-EXPANSION MARINE ENGINE

arrangement of such an engine is shown in the illustration. Nearly all compound and triple-expansion engines exhaust into condensers.

As these engines increase in power and weight, new forces must be taken into account. Strains that in a small engine are too small to notice become sufficient, in these large engines, to break the machine. One of the most important problems of the designer of a great engine is to balance the momentum of the tons of moving parts. This is accomplished with such delicacy that an engine developing 10,000 horse power may move at high speed without noticeable vibration.

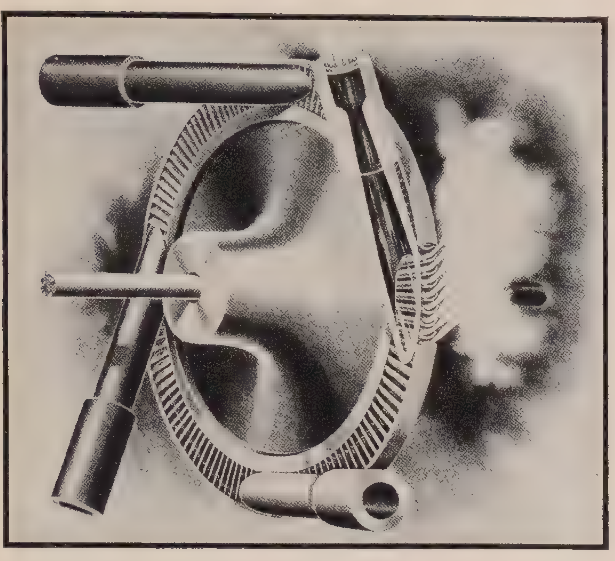
THE STEAM TURBINE

Strange to say, our latest and most effective kind of steam engine was made in a crude and simple sort of way more than two thousand years ago by Hero of Alexandria. His engine was a wheel driven by steam in much the same way that a lawn-sprinkler is revolved by water. If you push against something to shove it away from you, you also push yourself away from the thing. So the water from the sprinkler, pushing out against the air, turns the sprinkler jet around.

That is the first principle of one type of water turbine. The water, pushing out of the wheel under pressure, makes the wheel revolve. Use steam instead of water, and you have a steam turbine.

As steam expands through a nozzle, it gains in velocity. The pressure, of course, drops as the expansion takes place. By using this principle, Dr. Gustaf De Laval, a Swedish engineer, brought out the first practical rotary engine, or turbine, in 1889. As is shown in the "transparent" drawing, this was a disk or solid wheel, in the rim of which small vanes were cut. Against these vanes, nozzles shot jets of steam. In the illustration you can see how these nozzles expand toward the mouth. If steam enters the small end of a De Laval nozzle at 200 pounds pressure, it will leave the large end at the rate of forty-eight miles per minute! This causes the disk to revolve at a tremendous speed, which sometimes reaches thirty thousand revolutions per minute. This speed is, of course, too high to be of any commercial value, and is therefore reduced through gears so that the machinery driven may revolve at about one-tenth of the turbine's speed.

About the same time, Charles A. Parsons, an Englishman, also invented a turbine of entirely different character. His first patent was issued in 1884, so he began work even before De Laval. Instead of having all the velocity of the steam



THE DE LAVAL TURBINE

The wheel reaches a speed of thirty thousand revolutions a minute.

expended on one disk, Parsons strung a number of disks on a shaft and enclosed them all in a cylinder or drum. He did not use an individual steam jet for each set of blades, but blew a single current of steam from one end of the cylinder to the other, allowing it to act upon each disk in turn. Between each pair of revolving disks, Parsons placed a set of fixed vanes to guide the course of the current of steam. After passing through the vanes of one revolving disk, the steam was turned by these fixed vanes at exactly the right angle upon the vanes of the succeeding disk. When the steam had passed the length of the cylinder, it was discharged into a condenser. This type of turbine turns much more slowly than the De Laval, as it has a speed of about thirty-six hundred revolutions per minute.

A third type of turbine, combining the principles of both the Parsons and the De Laval, was invented by Charles E. Curtis, who was an electrical manufacturer in Brooklyn, New York, and one of the inventors of the electric fan. Curtis used a series of De Laval disks, each turning in its own separate compartment, and each disk having its own nozzles. After striking the first disk, the steam, instead of being discharged, passed into a chamber where it collected and was then sent through another set of nozzles against the second disk. Here again it accumulated, then was discharged against a third disk, and so on through perhaps a dozen stages. This was a very important invention, and since perfection it has in many cases replaced turbines of the Parsons type.

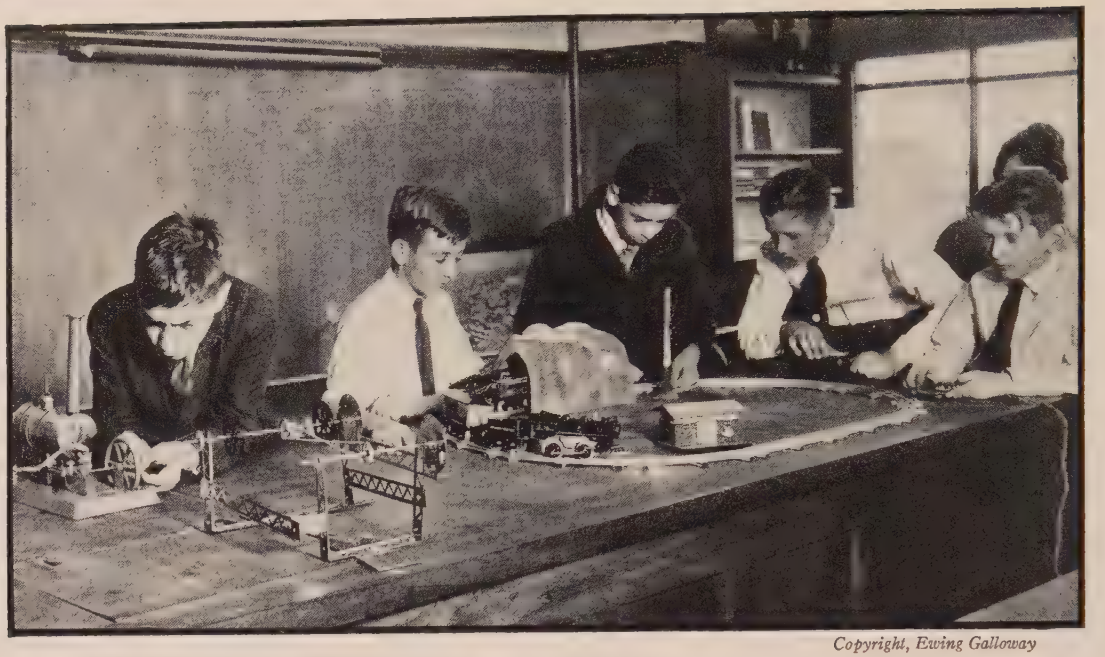
Turbine engines are of great use in swift steamships, as they run without vibration, and take up much less room than reciprocating engines. Many of the swiftest passenger liners and great battleships are equipped with these small but mighty motors, which are so effective and take up so little space. On the Parsons turbines used in one great transatlantic liner there are 1,500,000 vanes, and each low-pressure drum weighs 130 tons. The largest diameter of the drums is eleven feet eight inches. Reciprocating engines would occupy many times this space.

The use of the turbine in driving ships is really a small matter compared with its installation in power plants on land. It has replaced the reciprocating engine in many places, in some cases furnishing all power for a shop or factory, and in others driving the many auxiliary machines. It is now used almost exclusively in electric power stations, as it is more easily tended, requires fewer repairs, and is more economical for the high speeds required. By reducing its speed with gears, the turbine also finds use in supplying power for slow-speed machinery.

DEVELOPMENT OF THE LOCOMOTIVE

We are apt to think of the railroad as built for the use of the locomotive, and to-day that is strictly true. Yet there were railroads long before locomotives were invented. In 1630 such a road was in use in a coal mine in Newcastle, England, built of wooden rails on which cars were run by hand or horse power. Fifty years later a similar road was in use near the River Tyne, where one horse was able to draw four or five caldrons of coal at a load.

Iron rails took the place of the wooden ones about 1767, and ten years later someone conceived the idea of using single flanges for the wheels, the flange being placed on the outside. The first cars with wheels having flanges on



Copyright, Ewing Galloway

A PRACTICAL USE FOR TOYS

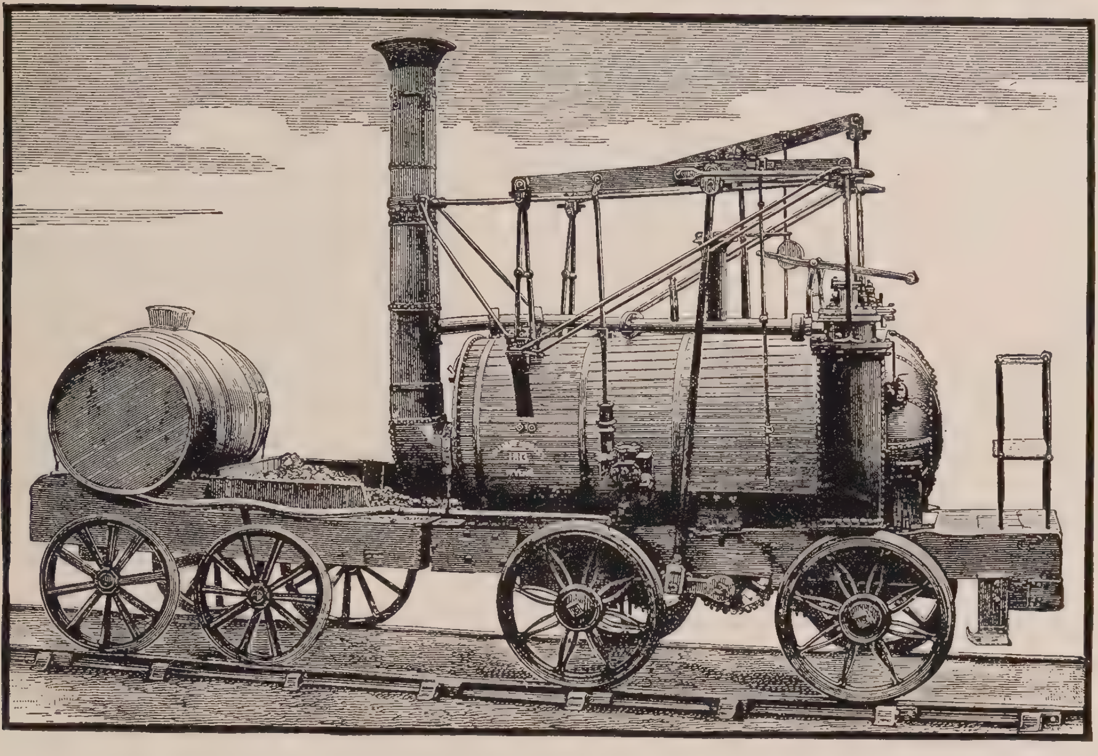
Schoolboys learn about machinery by studying electric trains and engines.

the inside, running on elevated rails, were built by William Jessop in 1789, and were so evidently superior that they were everywhere adopted. With minor changes this form of wheel and rail is in use to-day.

In 1802 Richard Trevithick of England produced a steam locomotive which hauled a wagonload of people over certain streets of London. But the roads were rough and the locomotive soon broke down. Two years later he designed another, which was built for a coal-carrying railroad in South Wales, and there on several occasions it hauled ten tons of iron at a fair speed. But this machine was not considered a success financially and was abandoned. Other inventors produced cable roads and engines which ran upon cogged wheels, but none were successful until George Stephenson entered the field.

Stephenson was born in 1781, in great poverty, in a small colliery village. He was put to work when a child and could not write his name until he was eighteen years of age. But he was industrious and ambitious, and by the time he was of age was a skillful engineer. At twenty-six he was holding a position as engineer for a coal-mining company. In 1814 an engine which he built for them was placed on the colliery tramway.

This engine showed many points of superiority over its predecessors, though it involved no new principles. It drew eight loaded wagons of thirty tons' weight, at a rate of four miles an hour, up a slight grade. But it would not keep up steam, and the noise of its exhaust frightened all the horses in the neighborhood. The authorities ordered Stephenson to stop the engine or stop the noise, and in his endeavor to find a way to do the latter he discharged the exhaust into the smokestack to muffle the sound. In this act he unwittingly solved the problem of the modern locomotive. Not only did the stack muffle the noise of the exhaust, but the force of the steam in it so increased the draft that double the amount of steam was generated. The chief obstacle in the way of success with the locomotive had been this failure to keep up steam, and the discovery made the path of future invention much easier. Stephenson built other locomotives, each an improvement, but the world knows him best by the success of the *Rocket*, built in his own



"PUFFING BILLY," 1813

An interesting forerunner of the modern steam horse.

establishment with the aid of his son Robert, and entered in a competition on the road between Liverpool and Manchester, at that time operated by cable.

A prize of $2500 was offered and the requirements were as follows:

1. The engine must effectually consume its own smoke.

2. The engine, of six tons' weight, must be able to draw, day by day, twenty tons' weight, including the tender and water tank, at ten miles an hour, with a pressure of steam upon the boiler not exceeding fifty pounds to the square inch.

3. The boiler must have two safety valves, neither of which must be fastened down, and one of them completely out of the control of the engineer.

4. The engine and boiler must be supported upon springs and rest on six wheels, the height of the whole not exceeding fifteen feet to the top of the chimney.

5. The engine with water must not weigh more than six tons, but an engine of less weight would be preferred, although drawing a proportionately less load behind it; if only four and one half tons it might be put on four wheels.

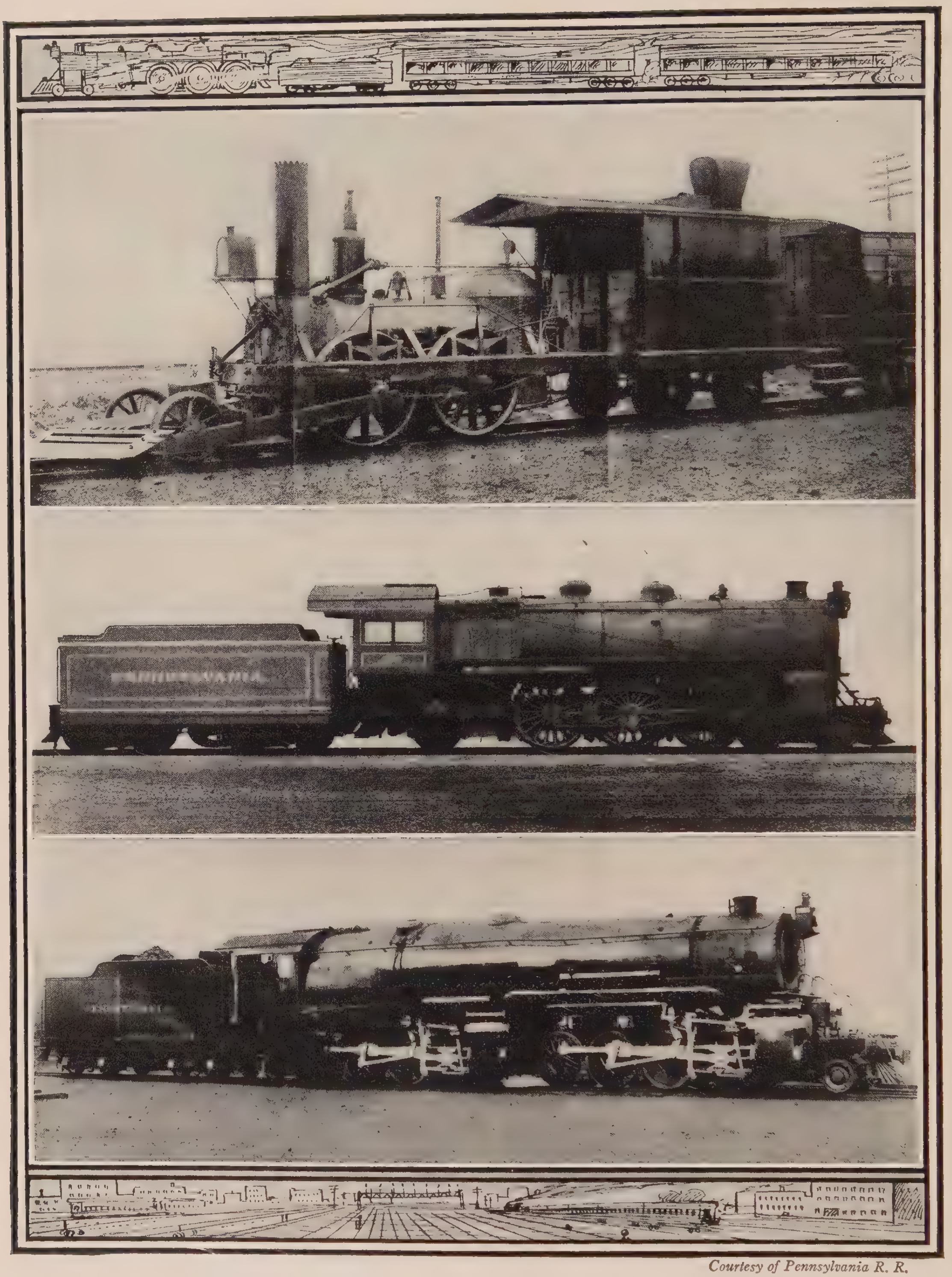
6. A mercurial gauge must be affixed to the machine, showing the steam pressure about forty-five pounds to the square inch.

7. The engine must be delivered, complete and ready for trial, at the Liverpool end of the railway, not later than October 1, 1820.

8. The price must not exceed £550 ($2750).

The first clause, requiring the engine to consume its own smoke, raised a problem that has not yet been satisfactorily solved. Still more of a stumblingblock was the speed requirement. Ten miles an hour seemed utterly absurd. One engineer stated publicly that "if it proved to be possible to make a locomotive go ten miles an hour, he would undertake to eat a stewed engine wheel for his breakfast." Nobody dreamed of what was to come in the way of sixty-mile-an-hour expresses.

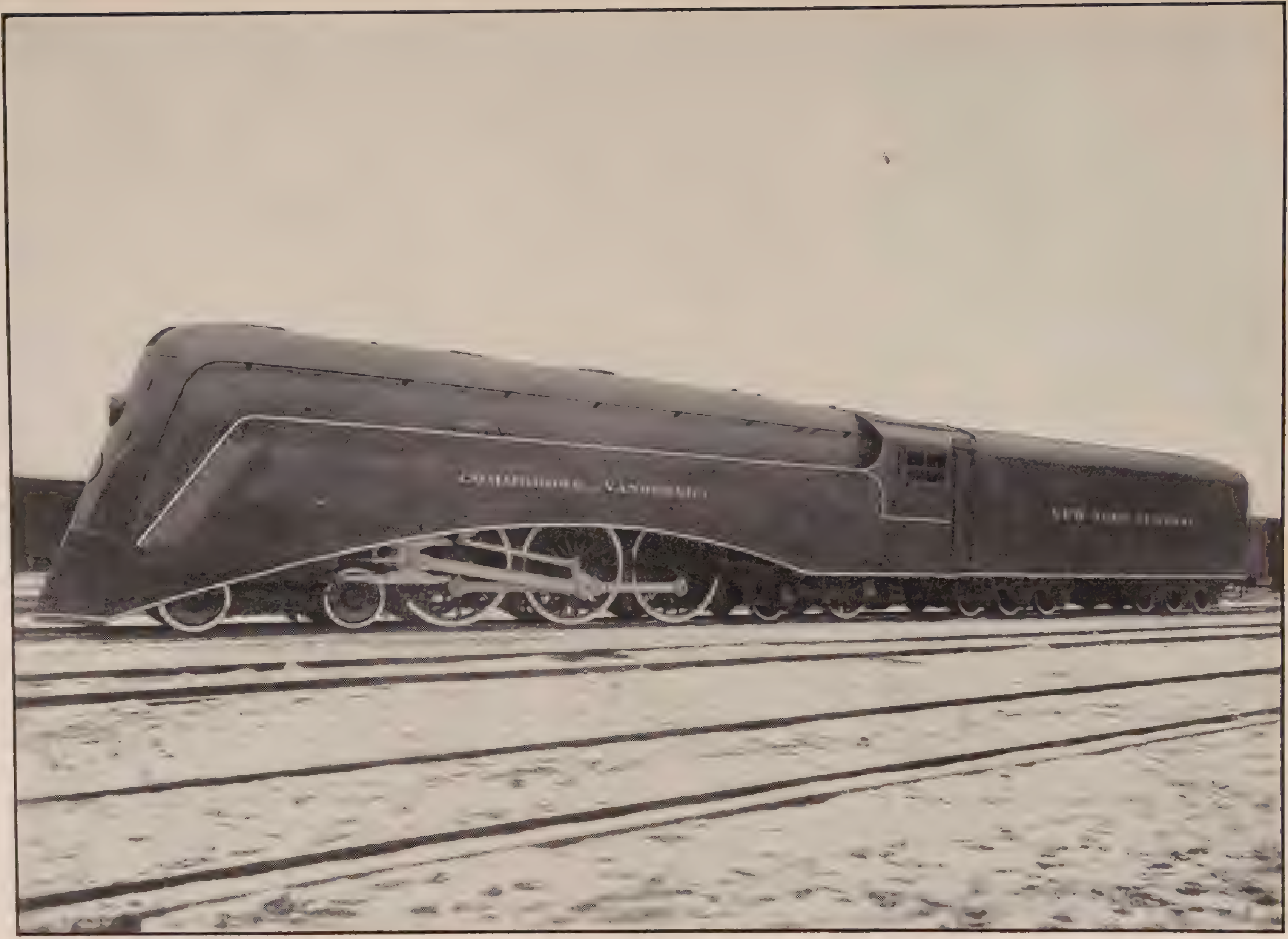
Four firms entered the contest, and named their engines the *Novelty*, the *Sanspareil*, the *Perseverance*, and the *Rocket* — the last being the Stephenson engine. The *Rocket* won, with the *Novelty* a close second. The *Novelty* has been humorously described as looking like a "milk can set in the rear of a wagon, with a little smokestack in front like a dash-



Courtesy of Pennsylvania R. R.

EARLY LOCOMOTIVE AND LATER FORMS OF DEVELOPMENT OF LOCOMOTIVE

A striking comparison of the first locomotive used on the Pennsylvania Railroad with two of later date on the same line.



Courtesy of New York Central Lines

A MODERN STREAMLINED STEAM LOCOMOTIVE

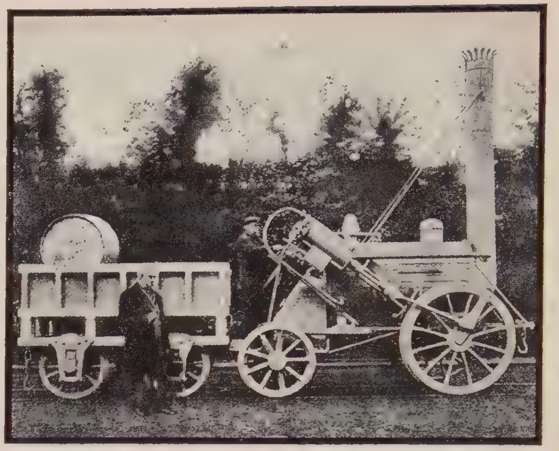
As in airplanes and automobiles, streamlining has been applied to steam locomotives to reduce air resistance and increase speed and efficiency.

board." It carried fuel and water in the "wagon box" part of the frame, in front of the boiler. On its first trial it reached a speed of twenty-four miles an hour, running without any load. That engineer ought to have eaten the "stewed engine wheel" at once. The trouble with the *Novelty* was that it kept breaking down.

The winner was Stephenson's quaint little *Rocket*, which looks queer enough when placed alongside a modern mogul. Its boiler was horizontal, cylindrical, with flat ends, six feet in length and three feet in diameter. Steam was stored in the upper half of the boiler. The lower half was filled with water and had copper pipes running through it. The two-by-three fire box was just in the rear of the boiler. Above the fire box and on each side were the cylinders, of which there were two. They acted obliquely downward on the engine's two front wheels. The piston rod, as in modern American locomotives, connected with the driving wheels by a bar fastened to the outside of the wheel.

From the first the *Rocket* proved a success. On the opening day of the contests it covered twelve miles over the two miles of trial tracks in a good deal less than an hour. Stephenson offered, the following day, to satisfy the curiosity of the great crowd present by an unofficial trial of his engine. Attaching it to a car into which thirty-six passengers were loaded, he took his guests on a ride at the surprising rate of from twenty-six to thirty miles an hour.

A serious defect in this engine was the inclination of the cylinders, which produced unsteadiness. Presently Timothy Hackworth suggested horizontal cylinders, and Stephenson adopted this plan in an engine which he called the *Globe*. He followed this with the *Planet*, which became the model for engine builders the world over. It is an interesting fact that since the time of the *Planet* the general shape and arrangement of the locomotive engine has continued the same. Cold and stormy weather in our country led to the building of the cab, or house, for the engineer and fireman; and many other improvements were made. The *Rocket* weighed a little over four tons; to-day the hundred-ton engine is a common affair. The demand for speed has brought a marked increase in the amount of steam pressure per square inch in the boilers. This has gone from 130 pounds in 1870 up to 160, and frequently 225, pounds' pressure. A much larger proportion of the energy of the steam is also utilized now, through the introduction of what is known as the "compounding principle." Compound locomotives came into use about 1890.



STEPHENSON'S "ROCKET"

From twenty-six to thirty miles an hour was good speed for this machine.

The increased size meant increased coal-consuming capacity; how to keep the fire box full became a problem. The big engines of the present time tax the strongest firemen. Mechanical stokers have been successfully applied to large locomotives. The use of oil as a fuel is another step towards higher efficiency.

While George Stephenson, an Englishman, built the first locomotive, the perfected railway engine of to-day is a combination of many inventions. Seventeen or more American inventors are represented in the huge structure which draws your heavy train so swiftly and so smoothly.

And finally, as the locomotive thunders at high speed over weblike bridges of steel and down steep mountain grades, the engineer sits calm and steadfast, knowing that locomotive and train are under sure control. He has only to turn a lever and every wheel will be gripped by viselike brakeshoes applied by the automatic air brake, the invention of George Westinghouse, an American.

See also the illustrations of the new Diesel-powered streamlined trains, Volume IV, pages 347 and 349.

AIR GOES TO WORK

IN converting the forces of nature to his own uses, man early took advantage of the power that lay ready to his hand in currents of moving air. Centuries ago, his ships moved upon the waters with their sails filled with the winds of the sea. Later, windmills ground his grain. Even now our farmers depend upon the windmill to pump the water or run an electric generating plant.

To a young Maine man, happily named Benjamin Franklin Sturtevant, goes the credit for the first use of air in industrial pursuits. His first invention was a simple suction fan to draw away the harmful dust from a shoemaking machine. From this sprang the protective fans, or "blowers," which remove dangerous and health-destroying dusts and gases in mills, mines, and factories. It led also to the device which sucks the grain cargoes from the holds of steamers and from freight cars, and to the vacuum cleaner which keeps our family rugs so spick and span.

We could mention also the sand-blast which cleans the brick and stone of our buildings through use of an air-blown stream of sand; the ventilating and air-conditioning systems of our newer schools, theaters and homes; the spray machine by which our automobiles are painted; the "forced draft" which blows air through the Bessemer converter and turns iron into steel. These are spoken of to give you a faint picture of the part played by air in our everyday life.

Air pumped into a storage tank may be compressed and kept in storage under high pressure. This compressed air exerts a power comparable to steam when it is allowed to escape, and like steam it is used to operate any number of important mechanisms. As early as 1849 a steam-driven rock-drill had been invented. Used in mining and tunnel building it could do as much as many men working with the old-time drills and hammers. It helped to build the Hoosac Tunnel in Massachusetts, the first tunnel constructed in the United States. Compressed air soon replaced steam as the power operating these drills. It has become the driving force of numberless pneumatic tools, such as the riveting machine which is used wherever steel is being fashioned, whether into building, bridge, or boiler.

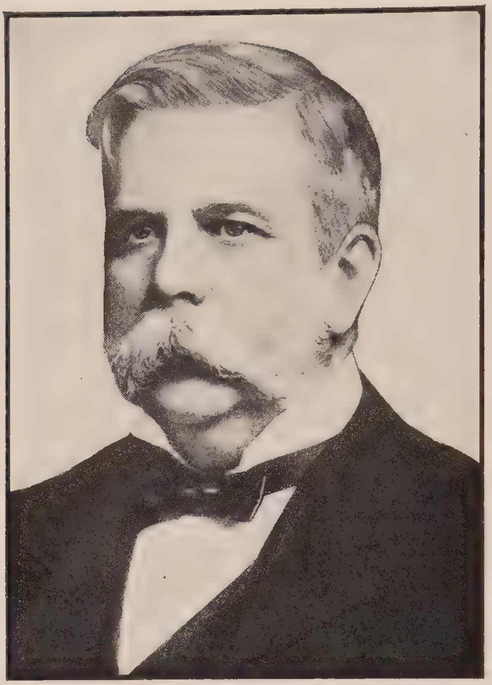
THE AIR BRAKE

Compressed air also made possible what is perhaps the most important of all the air-using mechanisms, the air brake. Trains are of such weight and travel with such speed that the system of hand brakes which at first served to bring them to a stop long ago became inadequate. Greater power and greater speed of application were needed. All trains the world over are now equipped with the Westinghouse automatic air brake, which makes it possible to apply all the brakes at once on all the cars of a train, no matter how long it may be. This is one of the most wonderful inventions connected with railroading.

George Westinghouse, inventor of the air brake, succeeded in interesting Andrew Carnegie and other Pittsburgh men in his device and they agreed to stand the expense of equipping a train. The first trial took place in October, 1868, on the Panhandle railroad between Pittsburgh and Steubenville. The experiment was so successful that the wonderful brake that could stop a train in its own length came into general use almost immediately.

How does it work? On the engine is a steam-driven pump which compresses the air into a reservoir beneath the engine or tender. A pipe leading beneath the train connects with a "triple valve," an auxiliary reservoir, and a brake cylinder under each car. The triple valve is the most important feature of the system.

When the engine is coupled to the train, the compressed air from the main reservoir passes into the train pipe, through the triple valve, and into the auxiliary reservoirs, in which it is stored at high pressure. As long as the pressure in the train pipe is kept up, the brakes remain in an "off" position. The instant the train pipe pressure is reduced, the triple valve shifts and allows the compressed air to flow from the auxiliary reservoir into the brake cylinder. There it pushes down the piston which forces the brakes against the wheels. When the pressure in the train pipe is again resumed, the air escapes from the brake cylinder and brakes are released. The force with which the brakes are



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GEORGE WESTINGHOUSE

The famous inventor of many devices for safety in traveling and for the general progress of the world.

applied depends on the reduction of pressure in the train pipe. A slight reduction applies the brakes gently; when all the air escapes from the pipe, the triple valve opens wide and the brakes are jammed on hard for emergency use.

THE INVENTOR OF THE AIR BRAKE

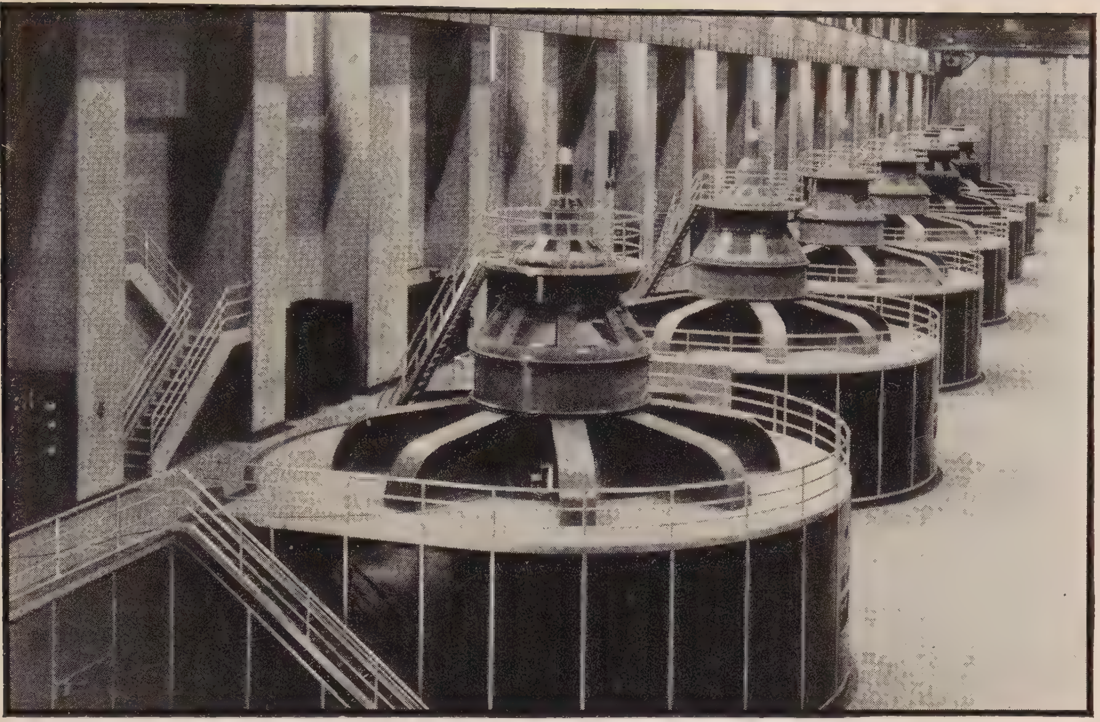
George Westinghouse was born October 6, 1846, at Central Bridge, N. Y. His father had invented one of the first threshing machines introduced into the United States. There were five boys in the family, and before they were sixteen years old, each had built an engine of original pattern with his own hands. George made a rotary engine when he was fifteen. He served in the Civil War and at the close of the war, after a short term at Union College, entered his father's factory at Schenectady, N. Y., and devoted himself to invention. The air brake was suggested to him by a railroad collision which he witnessed, and for which the poor brakes were responsible.

The mind of Westinghouse was always at work. No sooner was the air brake in use than he was developing other inventions, among them a device for transporting natural gas, which he perfected in spite of the jeers of leading engineers who had failed. Westinghouse was forced to fight opposition continually, but that is the lot of inventors. It was fifteen years before he was able to overcome the obstacles to the use of the alternating electric current which were deliberately thrown in his way. Yet the introduction of this system, experiments with which had been made in Europe, eventually won him almost as much fame as the invention of the air brake. Power can be transmitted a much longer distance by the alternating than by the direct current, and doubtless it is due to the stubborn persistence of Westinghouse that many of the smaller cities and towns have electric lights to-day.

As the World's Fair at Chicago approached, Westinghouse entered a bid for the electric-lighting contract which was one million dollars lower than that of the nearest bidder. He was given the contract, but in the face of violent criticism inspired by his enemies. The success achieved at the fair was so great as fully to demonstrate the value of the alternating system, and the managers were vindicated.

In 1912 he was awarded the Edison gold medal for his achievements in the development of the alternating-current system. He received it at a banquet which was attended by many engineers who had hotly opposed his efforts to introduce this system.

It is worth noting that some of the most important of Westinghouse's inventions had as their object the conservation of human life. He fathered the modern automatic railroad signal and devised the automatic couplers used in the New York subways. When one man does so much, some of his achievements are likely to be overlooked; but it is worth while pointing out that he was the originator of the Saturday half-holiday in this country. He was the friend of labor and understood the laboring man. He passed away March 12, 1914, universally recognized as one of the world's foremost inventors, and a captain of industry to whom this country owes much of its rapid development.



Courtesy of Westinghouse

ELECTRIC GENERATORS

ELECTRICITY

OUR MYSTERIOUS SERVANT AND WONDER WORKER

IF you rub a bit of amber, or resin, or a bit of glass on a dry coat sleeve you will find that it will attract bits of paper and hold them there. This is a manifestation of electricity. The ancient Greeks knew that amber would act in this way and they poetically said that the amber had a soul because it could attract. We do not know to-day what this force really is, though we call it electricity. As of old, in the Arabian tale, Aladdin rubbed the lamp and called forth a genie with mighty powers, so to-day man calls forth this same mysterious power which the rubbed amber showed the Greeks, and makes it light and heat and transport him round the world.

The Greeks said that the thunderbolt was a javelin hurled by Zeus, and not until Benjamin Franklin called this mysterious power down the kite string from the thundercloud into his Leyden jar did men know surely that Jove's thunderbolt and the soul of the amber were one. Yet both are manifestations of that still, mysterious force which we call electricity. We know its power; we harness and control its energies and make it our very slave, but we do not yet know what it is. Our huge generators call it up as Aladdin did the genie. We send it through a thousand miles of wire and make it do our bidding at the other end, but we do not know whence it comes or whither it goes. We call it a mode of motion or a manifestation of energy, but its very source is as unknown as that of life itself.

Its action in passing along a wire may be likened to the flow of water through a pipe. Even as a pipe must be clean and free from anything that will interfere with the flow of water, so a conductor of electricity must offer the least resistance possible to the passing of the current. One of the best materials for conductors is copper wire, and as copper may be

AN ELECTRICAL DISPLAY DURING A THUNDERSTORM

Copyright, Kolb Bros.

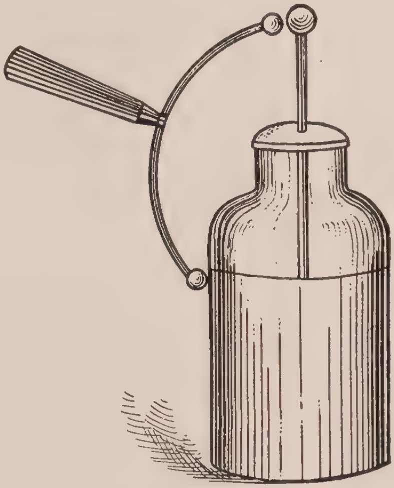
obtained in sufficient quantities to make the cost reasonable, it is what is generally used.

The walls of a water pipe form a barrier through which water cannot pass, and it flows along the inside of the pipe as it may be directed. Any holes or cracks in the pipe walls will allow the water to leak through, and, with a large enough leak, the flow of water in the pipe will cease. The copper wire through which electricity flows corresponds to the space inside of a water pipe. To prevent leakage and to cause the current to flow through the designed conductor the wire must be covered with some nonconducting or insulating material. This is usually made of fiber, rubber, or some other substance through which electricity will not pass. If this insulation becomes destroyed at any point, the leakage of the electricity at that point will short-circuit the current and it will cease to flow through the wire and will escape through the nearest conductor.

If an obstruction of any kind is placed in a water pipe, for instance, a substance through which water will pass only with difficulty, the energy of the water used up in trying to get through this substance will cause it to become heated. In the same way if electricity is forced through a poor conductor, one offering considerable resistance to the flow of the current, this material will be heated by the current. This is the principle of electric stoves and heaters.

BOTTLED POWER — THE LEYDEN JAR

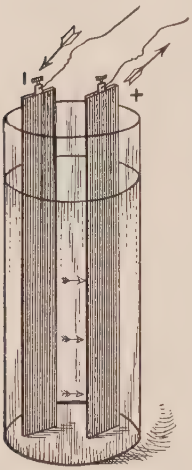
Two hundred years ago small machines were made in which, by turning a crank and making a glass globe or disk revolve, feeble electricity was generated. In 1745 Dean von Kleist, in Germany, discovered that this force might be bottled, that a nail or a piece of brass wire in a dry glass vial once electrified held the force for some time and might be made to give it forth in a somewhat startling way. Under the right conditions sparks would spring from it and people touching the nail received a severe shock. Out of this apparatus grew the Leyden jar, a glass bottle coated outside and in with tin foil, the two being separated by the glass. The inner coating is connected with a metallic knob protruding from the cork. To charge the jar the outer coating is connected with the earth and electricity is excited in the inner coating with an electrical machine. The machine excites a positive electricity on one side of the glass, a negative on the other, and the glass keeps the two apart. But if a path be provided for the two electricities to flow to one another, they will do so. Holding the "yoke" as in the illustration will cause a discharge of sparks to jump between the knobs of yoke and jar. In 1752 Franklin charged a Leyden jar from a thundercloud, by drawing the electric current down a kite string. This proved that lightning was but a manifestation of electricity. This kind of electricity is called "static." Franklin little realized the power of lightning, but fortunately escaped from this experiment with his life.



A LEYDEN JAR

ELECTRIC CELLS AND BATTERIES

We speak of electricity as a fluid because it seems to flow from one substance to another. If we put two metals in an acid solution which acts differently on the two, then, if there is a connection by wire, a "current" will flow from one to the other and then through the external wire circuit. If the wire is broken, the current stops. Thus we have the voltaic cell, invented by an Italian named Volta. Various metals and other substances are used, as well as various solvents, but the principle is the same in each case. Many voltaic cells connected by wires are called a "battery," usually a "galvanic" battery, from another distinguished Italian, whose studies in electricity led up to the invention of the battery.



A VOLTAIC CELL

The discharge of a Leyden jar is a miniature lightning flash, that of a galvanic battery is a current which may flow for a long time. It produces electricity in great quantity but of little pressure, and is in use in many ways where such an electric current is desired. The dry cell is now preferred because it contains no liquids and can be used in any position. A container of zinc is filled with an absorbent mixture soaked with chemicals, in which a rod of carbon has been embedded. A current will flow through a wire connecting the zinc case and the carbon rod. Another familiar source of electricity is the storage battery. This does not make electricity, but has the power of storing up current from a generator and giving it out again when a circuit is made.

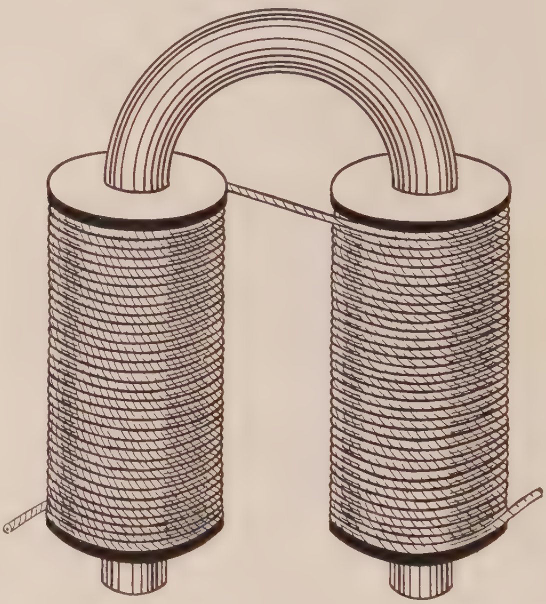
MAKING MAGNETS

The ancients knew of a kind of rock that would attract iron, and called it the "loadstone." It is an ore of iron and is a natural magnet. By rubbing steel with this rock the steel becomes magnetized, and thus primitive magnets were made. Magnets are now made by means of the electric current. The earth itself is said to be one great magnet. If a coil of wire through which an electric current is passing surrounds a bar of soft iron, it makes it a magnet while the current flows. Shut off the current and you have a bar of iron, not a magnet. By making and breaking the circuit the bar will alternately attract and release another bar of iron near it. In this lies the principle of the electric telegraph, the dynamo, the electric motor, and many other electrical devices. A simple apparatus devised on this principle is known as the "electromagnet."

ELECTRICAL MAGNETS

When an insulated wire is wound round and round a steel or iron bar from end to end, and its ends are connected with the terminals of an electric battery, a current flows round the bar and the bar is magnetized. Increase the strength of the current and multiply the number of turns of wire, and the attractive force of the magnet is correspondingly increased. Then disconnect the battery. If the bar is of iron, the magnet will lose its attractive force; but if of steel, it retains it in part. The first electromagnets were made in the shape of horseshoes or straight bars. Now two shorter bars riveted into a plate are generally used. Coils of wire wound round each bar are so connected as to form a continuous whole, but the wire of one coil is wound in the direction opposite to that of the other. The free end of each goes to a terminal of the battery.

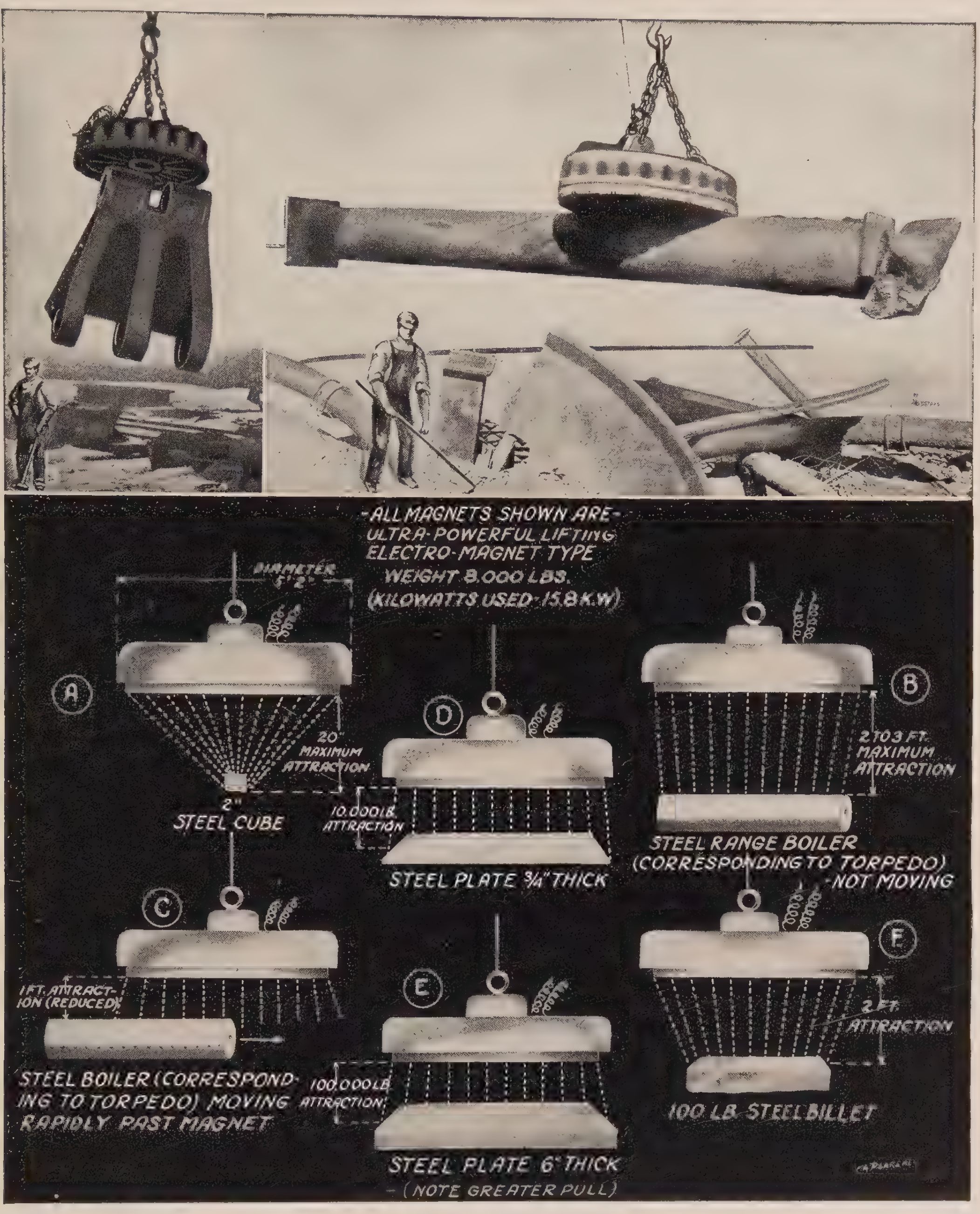
We have now considered electricity in two of its forms—static in the Leyden jar and current in the galvanic battery — and are ready to pass to some of its applications.



AN ELECTROMAGNET

A bar of soft iron wound with insulated wire from end to end. Notice that the wire is wound in one direction on the one pole and in the opposite direction on the other.

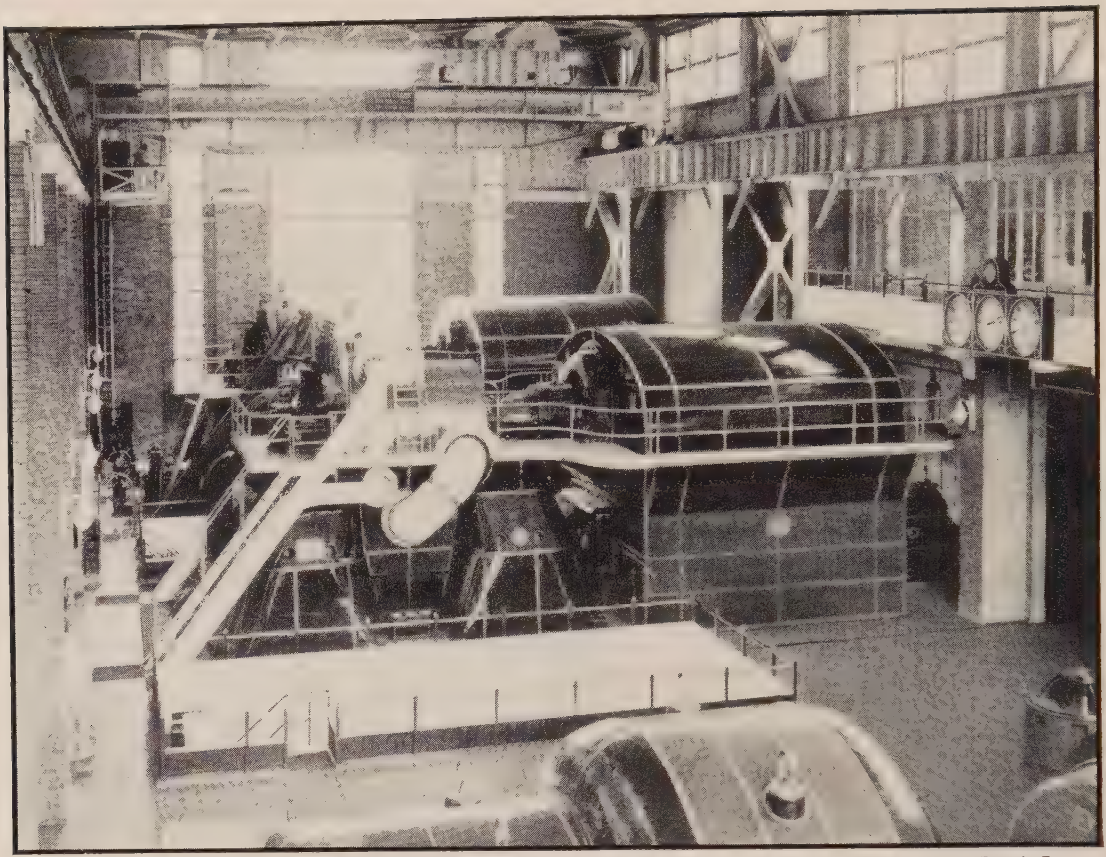
ELECTROMAGNETS LIFTING TWENTY AND THIRTY TONS



Courtesy Electrical Experimenter, N. Y.

HARNESSING THE WONDERFUL FORCE OF MAGNETISM

The electromagnet can attract only a comparatively short distance, but it can do wonders when it is set at work.



Courtesy of General Electric Co.

STEAM TURBINES AND GENERATORS IN POWER STATION OF FORD MOTOR COMPANY

ELECTRICITY TURNED TO POWER

IT is one of the great laws of the universe that energy cannot be created or destroyed. It can, however, be changed from one form into some other form or forms. There is no more interesting illustration of this law than in the electric generator, or as it was formerly called, the dynamo. This whirling machine is able to take mechanical power from the steam turbine or water wheel which drives it and turn that mechanical power into electric power. The electric power so generated may then be sent over wires for hundreds of miles to do all sorts of useful work wherever and whenever it is needed. Today we rely on this electric power to light our streets and our homes; to turn hundreds of motors, ranging in size from the huge ones in factories to the tiny ones in electric clocks; to heat our electric irons and electric toasters, and to do countless other things for us.

THE LAW OF THE DYNAMO

It is a well-known fact that a certain invisible influence exists around the ends of the poles of a magnet. If these two poles are brought near each other, the space between them is affected by both. This influence is spoken of as "magnetic lines of force" which are imagined as passing from one pole to another. It is also called a "magnetic field." If a coil of wire is connected with an instrument which indicates the presence of an electric current and is moved through this magnetic field, an electric current will pass through the wire while it is moving across the lines of force. This fact was discovered by the British scientist Faraday

Courtesy of Tennessee Valley Authority

ELECTRIC POWER FROM FALLING WATER

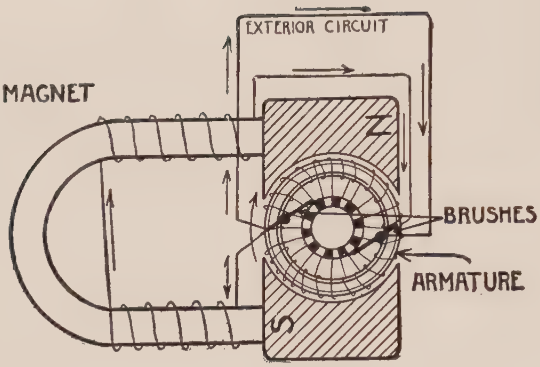


DIAGRAM OF A SIMPLE DIRECT-CURRENT GENERATOR

in 1831. It was found that only while the wire was in motion was the current present. The next step was to mount the coil of wire on a spindle and keep it rotating in a magnetic field. The motion was thus made continuous and a steady current generated.

THE DYNAMO OR ELECTRIC GENERATOR

By winding a large number of coils on one spindle and driving the spindle by an engine at high speed, this simple method of generating electricity was made the basic principle of the first practical electric generators. The first of these machines was constructed by Faraday in 1832 and was called a "dynamo," a word derived from the Greek word for "power."

In order to collect the current thus generated, two copper rings were attached to the revolving spindle, one being insulated from it, and the ends of the coils were connected each to one of the rings. Two flat pieces of copper or carbon called "brushes" rested against the rings as they turned with the spindle, and the two ends of the external circuit were connected to these brushes. As this collection of wire coils, called an "armature," rotates between the magnet poles, each coil will pass through the lines of force twice in every revolution, the first time moving in one direction and the second in the opposite, and between these passages the coil will pass out of the influence of the field. This will cause the generation of two complete currents for each revolution of the coil, and these two currents will flow in opposite directions. There results in the external circuit, not a continuous current, but in reality a series of current pulses, alternating in direction. This is the principle of the alternating current. In an armature where there is a large number of coils, the number of changes or pulses of the current will depend on the number of the coils and on the speed of rotation.

THE ELECTROMAGNET

It was soon found that the permanent steel magnet would not furnish a sufficiently strong field to produce a current of any considerable commercial value. We have already seen that if a piece of soft iron is surrounded by a coil of insulated wire containing an electric current, the iron becomes to all intents and purposes a magnet so long as the current is in motion, and no longer. Furthermore, the strength of the magnetic field increases as the current sent into it is increased. This is the electromagnet, the principle of which is used in all generators and motors of today.

While the alternating current is used for most purposes, there are certain cases where it is an advantage to have a current flowing continuously in one direction. A continuous-current or a direct-current generator was accordingly designed. This really produces an alternating current which, when it leaves the armature coils, is changed into a direct current. To accomplish this the brushes are set, not in contact with rings connected directly to the coils, but with a commutator consisting of a number of copper bars insulated one from the other and connected with the armature coil at regular intervals. These connections are so

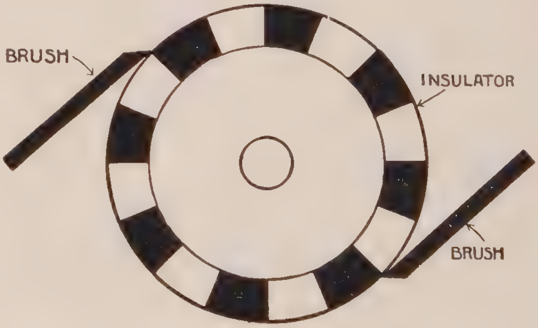


DIAGRAM OF A COMMUTATOR FOR A DIRECT-CURRENT GENERATOR made that the current leaving the armature and passing through the commutator against which the brushes rest is delivered to these brushes as a continuous current and not as a series of alternating pulses.

Thus far generators have been spoken of as having a fixed magnetic field and a rotating armature in which the current is induced; but these may be reversed, and so we have some generators in which the electromagnets form the moving part, the armature coils being stationary. On these simple principles rests the generation of electricity, which, transformed into power, is doing to-day a large part of the work of the world.

THE ELECTRIC MOTOR

Even before the discovery of the Leyden jar and of the electromagnet, experimenters had succeeded in causing pieces of metal to revolve under the influence of static or frictional electricity. These were actually small motors, but of course had no practical value. The electric motor with which we are familiar was an accidental invention. Had it not been for the carelessness of a workman, we might even to-day be without this almost universally used source of power.

Our electric motors are direct descendants of the direct-current generator produced in 1870 by the Belgian, Z. T. Gramme. A number of these machines were being set up at an industrial exposition in Vienna in 1873. When making the electrical connections to one of the generators, a mechanic accidentally attached to it the wires from another generator which was already in operation. Its armature immediately began to revolve with great rapidity. It was at once apparent that this machine was acting as a motor, turning electricity into mechanical energy. It is thus seen that generators and motors are similar in their principles of construction.

NIAGARA IN HARNESS

Of course a generator driven by a steam engine gives out no more power than the engine produces. Indeed, some power is lost in transmission. The generator and the electric motor simply make the use of the power more convenient, for between the two it may be carried miles on a slender wire.

Falling water, by means of turbines (already described), produces power which is continuous and very cheap. Now that generators permit us to transmit this power to a distance, water power is again filling an important place in the doing of the world's work, a place which it lost in part when steam came into use.

One of the greatest opportunities for using the power of falling water in the United States and Canada is at Niagara Falls on the Niagara River. Through this river flows practically all of the water from the Great Lakes, which have a total surface of almost one hundred thousand square miles. An average of 210,000 cubic feet per second flows over the Falls, falling about 50 feet in the upper rapids and 165 feet in the single drop at the Falls. The total power of Niagara Falls is estimated at five million horse power. The present equipment in power houses is over one and one-half million horse power and the annual output exceeds six billion kilowatt-hours of electrical energy. Great transmission lines carry a large part of this power to Buffalo and to scores of other cities and towns, some of them many miles distant.

By tapping the river about a mile above the Falls the water is led through both a canal and a tunnel to a forebay at the brink of the cliff below the Falls. The canal was first constructed in 1857 and has been widened and deepened several times. The tunnel was completed in 1923 and is horseshoe-shaped, about 32 feet in height and in width. From the forebay the water is conveyed by huge pipes called penstocks through the solid rock to the turbines in the power house at the foot of the cliff, about 210 feet below. These turbines are direct-connected to the generators and vary in size from ten thousand horse power to seventy thousand horse power.

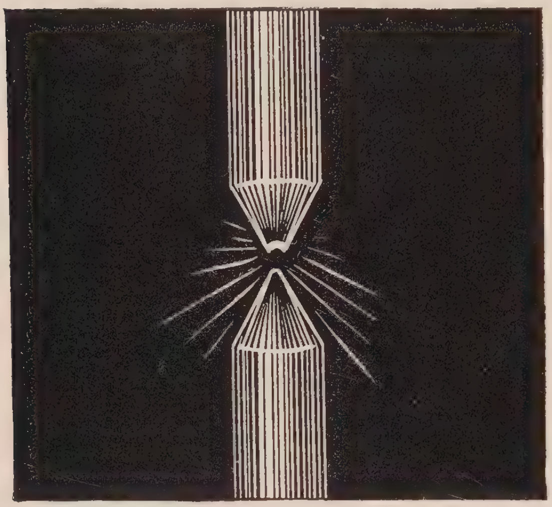
So that the grandeur of the Falls will not be marred by directing too much of the water through the flumes, a treaty between the United States and Canada limits the amount of water which can be diverted for the generation of electrical power. The great power stations at the Falls have been the cause of the establishment of many manufacturing plants in that vicinity, all of which depend for their power on these central stations.

HOW ELECTRICITY PRODUCES LIGHT

FOR thousands of years, ever since man first held aloft a burning fagot for a torch, man-made light was the result of burning something — a stick of wood, a candle, oil or kerosene in a lamp, or gas. But with the coming of electricity it became possible to have light without fire.

THE CARBON ARC LIGHT

If two pointed pieces of carbon, each of which is connected to a terminal of a battery or other source of electricity, are brought into contact and then separated, an electric flame or arc will appear between the separated points and the points themselves will become white-hot. This intense heat vaporizes the carbon and a stream of carbon vapor is continually passing between the points. This vapor is a poor conductor of electricity, so that while the current will pass through it, yet the resistance to the electric flow causes the vapor particles to be heated to the point of incandescence and they give off light. The white-hot carbon points, however, emit much more light than the heated vapor. These facts were discovered by Sir Humphry Davy in 1800, and he constructed the first arc light. But it was not until 1878 that arc lights became commercially practical. For many years they were widely used for street lighting but today they are rarely seen, having been replaced by incandescent lamps and other newer types of lamps.



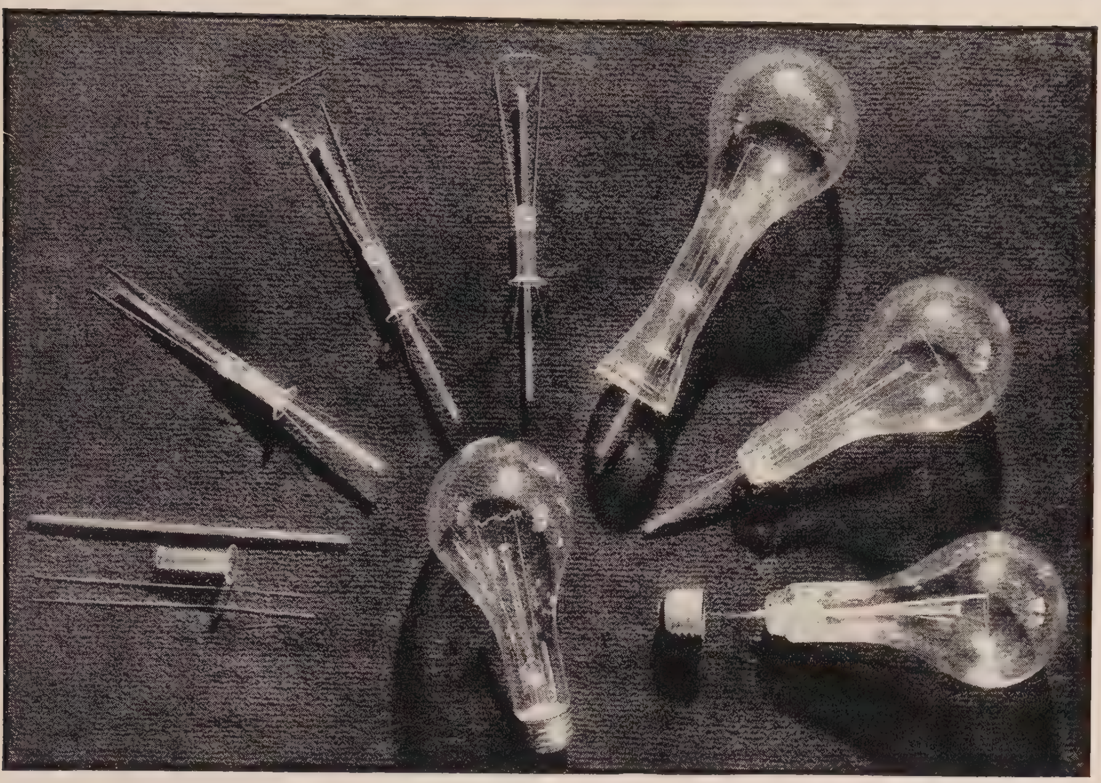
CARBONS OF AN ARC LIGHT

THE INCANDESCENT LAMP

The real era of electric light began in 1879 when Thomas Edison invented the incandescent lamp. This type of lamp, now greatly improved, is our ordinary "light bulb." Its principle is a simple one. Edison knew that an electric current passing through a very thin carbon wire or "filament" would make the filament glow, white hot. But in the open air it would quickly burn and break the circuit. His great invention was to put the filament in a vacuum where, having no oxygen, it could not burn. He did this by sealing the filament into a glass bulb from which all the air was pumped out. Today we use tungsten wire instead of carbon for the filament; and, in place of the vacuum, fill the bulb with argon, an inert gas. But the principle is still the same, and we owe to Edison an immense debt of gratitude for giving us a far better and more convenient source of light than the world had ever before known.

More than half a billion incandescent lamp bulbs are made each year, and they are made in ten thousand different styles and sizes. The largest is a 50,000 watt lamp, bigger than a basketball, used occasionally for special flood-lighting purposes. The smallest is the size of a grain of wheat, and is used in medical instruments. Every lamp must be free from the slightest trace of moisture. One drop of water distributed in 100,000 lamps is enough to cause early bulb blackening in all.

The most important part of an incandescent lamp undoubtedly is the simple appearing filament which supplies the light. The tungsten filament wire is the strongest wire known. Before it has been heated to incandescence it is half again as strong as the best grade of steel wire. Although tungsten is a relatively common element, 3-watt filament wire costs about $20,000 a pound to manufacture. Such filament wire is about one-tenth the diameter of a human hair and is wound into coils with over 2,100 turns per inch.



Westinghouse

ASSEMBLING AN INCANDESCENT LAMP

Here are the seven steps in the manufacture of an incandescent lamp. Workers start with two glass tubes, two strands of wire and a tungsten filament coil. They are assembled automatically into a "mount," which is placed inside of the bulb. Machines then seal the two together, pump out the air and replace it with argon gas, seal the tube and attach the base.

THE FLUORESCENT LAMP

Since 1939 an entirely different type of electric lamp, the fluorescent lamp, has been manufactured. It is long and tubular in shape, has no filament and gives more than twice as much light as an incandescent lamp for the current consumed. The long tube has an electrode at each end and is filled with a mixture of mercury vapor and argon gas. Electricity passing through this mixture creates invisible ultraviolet rays. These, in turn, bombard a coating of chemical compounds known as phosphors, on the inner wall of the tube, causing them to glow and produce visible light. Fluorescent lamps give cool light; in fact, the reason for their high efficiency is that little energy is lost as heat. You can put your hand on a fluorescent lamp even though it may have been brightly lighted for hours.

MERCURY VAPOR LAMPS, SODIUM VAPOR LAMPS AND NEON SIGNS

Mercury vapor and sodium vapor lamps emit light because of the passing of electricity through metallic vapors in a small cylinder inside an outer glass jacket. Mercury vapor lamps are useful for industrial lighting where a very strong light is needed and color is not important. Their cold greenish light gives high illumination but distorts colors.

Sodium vapor lamps give off a rich golden light and are often used for highway lighting. They are used at intersections, tunnel approaches and other dangerous places.

Neon signs are made of long slender vacuum tubes containing small amounts of neon gas. The gas is made to glow by the passing of high-voltage current. The tubes are bent into the shapes of any desired letters or designs.

THE TELEGRAPH

ONE of the most wonderful inventions ever worked out by man is the telegraph. Samuel F. B. Morse, whose genius gave this instrument to the world, was, strangely enough, an artist, who went to England to study with the famous Washington Allston.

Morse was born in 1791 at Charlestown, Mass., and educated at Andover and Yale. During four years in England he won marked success as a painter and sculptor, and was cordially received on his return to Boston. There his works failed to sell. Almost poverty-stricken, he moved to Charleston, South Carolina, where he accumulated some money by painting portraits. He founded the National Academy of the Arts of Design and as its president delivered lectures and enjoyed much popularity. In the meantime, his parents and his wife had died, and he returned to Europe to spend three years in the study of art in Italy and France.

But, in spite of his talent for painting, it turned out that Samuel Morse did not remain an artist after all. It happened that one day when crossing the ocean he overheard at table a discussion about electromagnetism and was greatly interested when told that electricity passed without difficulty through wires of any length.

"If that is so," said Professor Morse, "why should not intelligence be transmitted by electricity?"

Morse was then forty years old and had already secured several patents on other inventions. He set to work, denying himself every comfort, and put all his time and money into the perfection of this new idea. In a tiny room in a down-town New York office building he ate, slept, and worked, cooking his own simple meals and laboring far into the nights. At last the instrument embodying his idea was made. Then, on March 3, 1843, the future of the device was to be decided. Before Congress was a bill to put into operation a forty-mile telegraph between Washington and Baltimore. The House had passed the bill. On the decision of the Senate hung Morse's fate. Anxiously the inventor presented himself at the Capitol to await the news which meant so much to him. He stayed until nearly midnight and then went back to his hotel discouraged because the Senate had so much business that it seemed impossible for any decision about the telegraph to be reached that night. But the next morning he was astonished to be congratulated by Miss Annie G. Ellsworth, the daughter of the Commissioner of Patents, and to learn that the bill to install the telegraph had really passed.

S. F. B. MORSE

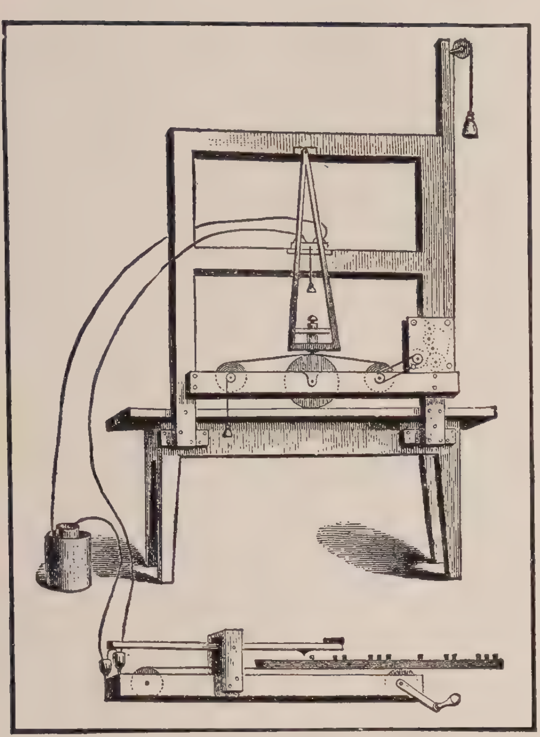
This famous inventor was awarded numerous honors by foreign governments, among them orders, crosses, and large sums of money. Probably no other American has received so many marks of distinction.

"You shall send the first message," said Professor Morse to Miss Ellsworth.

Later, when the line was ready, he asked her to dictate it.

"What hath God wrought?" were the words of the first telegram flashed over the wire.

Mr. Alfred Vail, a friend of Professor Morse, received the message at Baltimore and repeated



From "Inventors." Copyright, Charles Scribner's Sons

THE FIRST TELEGRAPHIC INSTRUMENT AS EXHIBITED IN 1837 BY MORSE

it, and afterwards a few other messages were sent and promptly answered. The telegraph was a success!

On May 26, 1844, two days after the sending of this first message, the National Democratic Convention met in Baltimore and nominated James K. Polk for President and Silas Wright for Vice President. Mr. Wright chanced to be in the Senate when the news was telegraphed by Mr. Vail from Baltimore to Professor Morse, who was in the Capitol building at Washington. When the message was taken to Mr. Wright he at once said: "Tell them I cannot serve." Back over the wire went the dispatch. When it was received at the convention it was credited merely as an attempt of Mr. Wright's enemies to take the election from him. A committee was sent to Washington to find out the facts. The next day they returned. The message delivered over the wire was correct! After this proof no one doubted the usefulness of the telegraph.

In the meantime an Englishman and a German were also trying to perfect a telegraph, and when Mr. Morse went to Europe to try to get his instrument installed there he met them. Each of the three applicants presented his invention before the foreign board, and then the German inventor, who had been examining Professor Morse's machine, cried, "Gentlemen, I willingly withdraw from the field. Mr. Morse's invention is better than mine."

About fifteen years later, in 1858, the first Atlantic cable was laid. Following this idea the telegraph and cable service was extended until it was possible for Queen Victoria, on the sixtieth anniversary of her accession to the British throne, to touch an electric button in her palace and send to forty distant parts of her realm the message:

"From my heart I thank my beloved people. May God bless them."

Within sixteen minutes a reply came from Ottawa, Canada, and before the queen had reached London Bridge responses had come from the Cape of Good Hope, Africa, and from Australia.

EXPLANATION OF THE TELEGRAPH

The electric telegraph in its simplest form consists of a single zinc-coated, iron or hard-drawn-copper wire connecting the two places between which messages are to be sent, with two instruments, and a battery for producing the electric current at each end. One of the instruments at each end is the transmitter for sending, and the other the sounder for receiving electric impulses, by which, by means of arbitrary signs, communication is carried on. The long line of wire is connected at one end with the transmitter or key. This is connected through the battery with the sounder, from which a wire runs to the earth.

On the other end the long wire connects with the sounder, then through the battery to the key, and from there to the earth. The earth acts not as a conductor of electricity in the sense that the wire does, but as a place where it may be stored, so that when a current passes through the long connecting wire the amount of electricity taken from the earth at one end will be restored to it at the other.

The action of the telegraph is somewhat similar to that of the electric bell. The key or transmitter which is shown in the illustration corresponds to the push button, and is simply a switch, the two points of which are held apart by a spring, and by which the circuit may be closed by pressing down on the button at the left. When the key is not in use the circuit is closed by pushing the small lever in the notch as shown, so that messages may be sent from the other end.

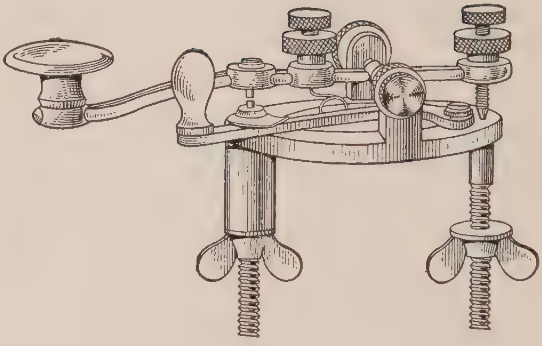
The sounder, which produces the audible signals, corresponds to the electric bell. It has an electromagnet opposite the ends of which a piece of soft iron is arranged connected to a lever, so that when the circuit is closed by the key at the other end, the soft iron immediately jumps into contact with the electromagnet and causes the lever to click against a curved bar, which it may hit both going up and coming down. It is by the variation in length and intensity of these clicks that the message is spelled out by the operator. The telegraph sounder differs from the electric bell in that there is only one up-and-down click for one depression of the key.

The characters used by Morse to designate the letters of the alphabet, numerals, etc., were made up of long and short dashes, dots, and spaces arranged in various combinations. The first machine invented by Morse was arranged to trace on paper these combinations. The clicks were not used until a later period. Hence the reason for using dots and dashes for characters.

The simple instruments invented by Morse have since undergone many improvements, although there has been no radical departure from his idea.

THE RELAY

Sending by direct current over a wire charged with a battery at the sending end can only be done for a limited distance. For a long time long-distance messages had to be repeated at intermediate stations. By the invention of the relay this difficulty has been overcome. A relay is an instrument that responds to the message which it receives and sets in motion a new battery, known as the "local battery."



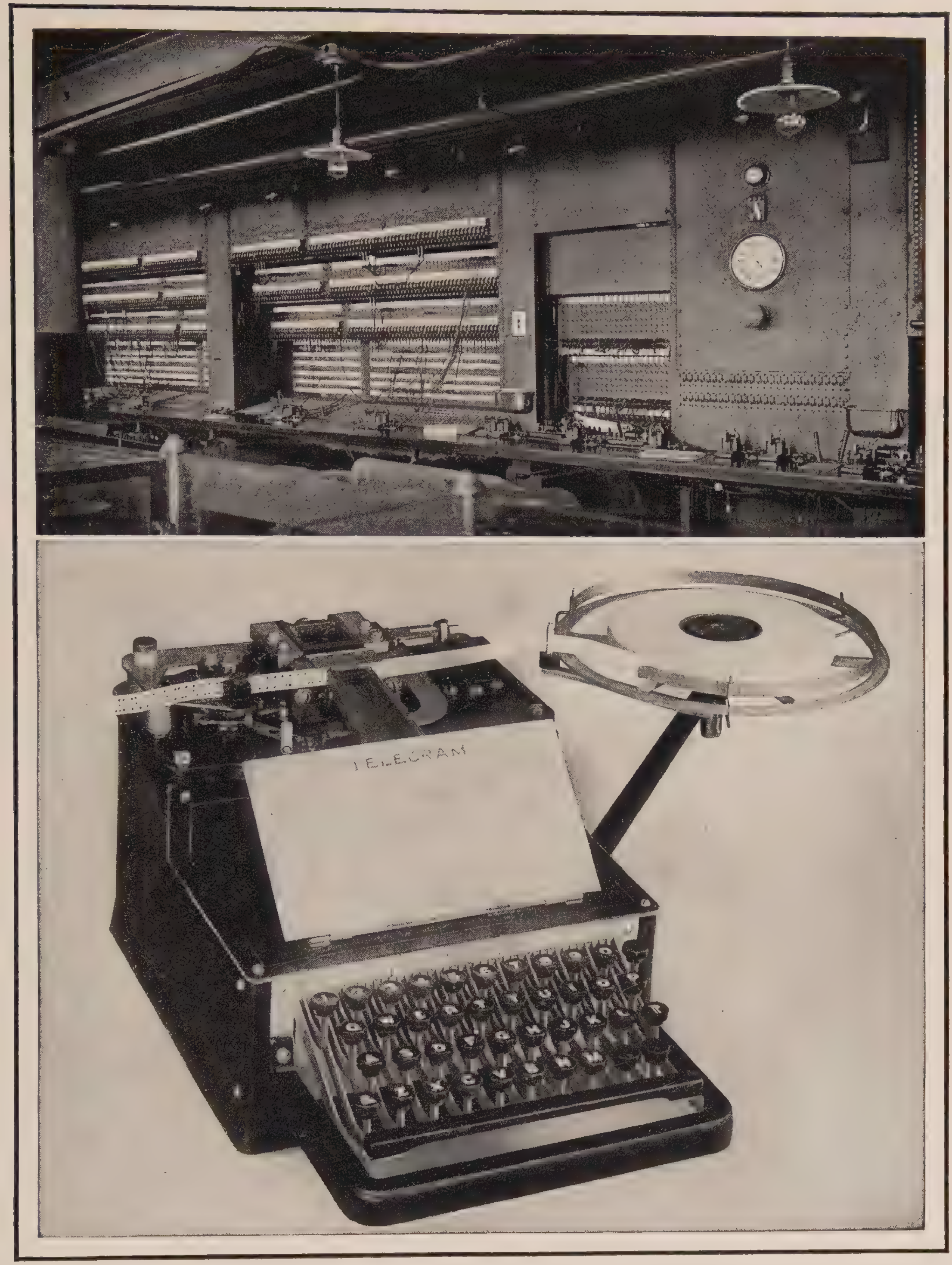
A TELEGRAPH KEY

MULTIPLEX TELEGRAPHY

The next great advance was the discovery that two messages could be sent, in opposite directions, over the same wire at the same time. This was called "duplex telegraphy." It was soon followed by quadruplex and multiplex telegraphy. This is done by connecting one of the instruments attached to a wire, so that it is only sensitive to the impulses which *come out of the wire*, while another set sends signals *into the wire*.

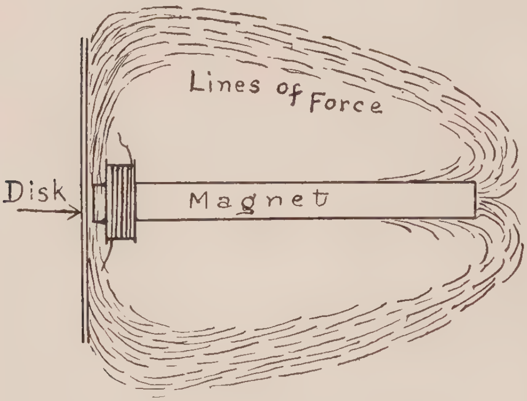
THE ELECTRIC CABLE

In August, 1858, the stupendous feat of laying an electric cable twenty-five hundred miles across the Atlantic Ocean was accomplished after several failures, and messages were sent by its means, showing how vastly invention and enterprise had extended the power and scope of the electric telegraph. A hundred minor inventions and devices had gone to this increase of power, the greatest of these perhaps being the insulated cable, for on no part of the twenty-five hundred miles must the inclosed wires allow the electricity to escape into the sea. In that case the message would fail. In addition to this, the cable must stand the wear and tear of rough rocks and the sway of currents. Thus the first cable laid between Calais and Dover across the English Channel soon gave out. But in 1851 another was laid, which is said to be in use to this day. The conductor of this cable was not a single wire of copper, but four wires, wound spirally to combine strength with flexibility, covered with



TOP: LOOP BOARD ON CIRCUIT SWITCHING SYSTEM OF A LARGE TELEGRAPH OFFICE. BOTTOM: TAPE PERFORATOR USED IN AUTOMATIC TELEGRAPHY gutta-percha and inclosed in tarred hemp. To impart additional strength, ten iron wires were wound around the hemp. This idea has been carried out in every subsequent cable.

In the Atlantic cable laid from Nova Scotia to Ireland in 1894, the central copper core is covered with gutta-percha, then with jute upon which steel wires are spirally wound, followed by a strong outer covering. For the greatest depths at sea, a cable with a diameter of seven eighths of an inch is employed. It is used for 1420 miles. As the water lessens in depth the sheathing increases in size until the diameter of the cable becomes one and one sixteenth inches for 152 miles. The cable undergoes two other enlargements until, as it touches the shore, for a distance of one and three quarter miles it has a diameter of two and one half inches. The weights of materials used are: copper wire, 495 tons; gutta-percha, 315 tons; jute yarn, 575 tons; steel wire, 3000 tons; compound and tar, 1075 tons; total, 5460 tons. The telegraph ship *Faraday*, specially designed for cable laying, accomplished the work without accident.



LINES OF FORCE SURROUNDING A MAGNET

Showing the change made in their shape by bringing a metal disk against them. This is the principle on which the telephone is based.

THE TELEPHONE

IN this age of great inventions it is difficult to say that any particular invention is the greatest. Yet the telephone, in point of its far-reaching usefulness, ranks very close to first place. The telephone has one great advantage which is not possessed by any other form of long distance communication. When you send a letter, or even a telegram, you must wait for your reply. But when you make a telephone call, no matter whether it is to the house next door or to a distant city, it is just as if you were talking with someone right in the same room with you.

Something of the great usefulness of the telephone is shown in the fact that in the United States alone some thirty-two billion telephone conversations are carried on each year. There are approximately 22,000,000 individual telephones now in use in the United States, a greater number than in all the other countries of the world put together. From any one of the twenty-two million telephones one may talk with practically any town or city in our country. Also, transatlantic telephone service now makes it possible for Americans to speak with persons in the British Isles and on the European continent. Even ship-to-shore conversations are now carried on by wireless telephone. Radio and the long distance telephone have something in common, as both employ the familiar vacuum tube that amplifies the voice and makes possible its clear transmission over thousands of miles.

THE FIRST TELEPHONE

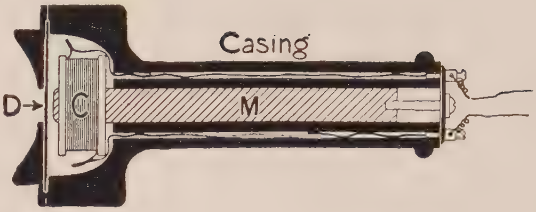
The first telephone that came into general use was that invented by Alexander Graham Bell, who at the time was not so much interested in telephones as he was in discovering a way of conveying speech to deaf persons by means of sound vibrations. It occurred to him that the vibrations set up by the voice might be made to act upon electric currents and thus affect some form of electric mechanism. He hit upon the telephone and made all posterity his debtor. He knew that the air surrounding the poles of an electromagnet was crowded with invisible "lines of force" and that these lines of force might have their shape altered if the surface of a metal disk were brought against them. If the disk were to vibrate with the sound of the voice, these lines of force would be made to undergo similar vibrations, and if the magnet were in connection by means of wire with a similar magnet at the other end, the lines of

Courtesy of the National Broadcasting Company

TELEPHONE LINES CONNECT THE STATIONS OF THE NATION-WIDE RADIO NETWORKS

This picture shows the control room of a broadcasting chain or network. The radio stations represented by lights on the large wall map are all sending out the same program, brought to them over thousands of miles of leased telephone wires from one central studio.

force at that magnet would be thrown into vibration, and a metal disk arranged as in the first case would vibrate correspondingly and the voice sound waves would be reproduced. All this is shown in simple diagram in the illustration given here, which represents the simplest form of telephone instrument. The casing, made of wood or ebonite, has a bar magnet, *M*, running through its center lengthwise, till the end protruding into the cup at the left end of the casing almost comes into contact with the metal disk, *D*. Around this protruding end is wound a coil, *C*, of fine insulated wire, which "picks up" any disturbances in the lines of force and sends them, like little electric pulse beats, along the wires to another instrument just like this one, only located at the other end of the line. This one instrument is both a receiver and a transmitter. On a line set up with such instruments no battery is needed, as the magnets themselves supply the necessary "current" sufficient to permit conversations for several miles, though one must listen very carefully as the vibrations are exceedingly small, often not exceeding one ten millionth of an inch. An ingenious "electrical boy" can without much difficulty string to a neighbor's house such a line as that of which a diagram is given at the foot of the page, and he will have accomplished what was the marvel of a generation ago, the carrying of speech by electricity, the bringing of a "voice from afar," which is the first meaning of the word "telephone."



A SIMPLE TRANSMITTER-RECEIVER

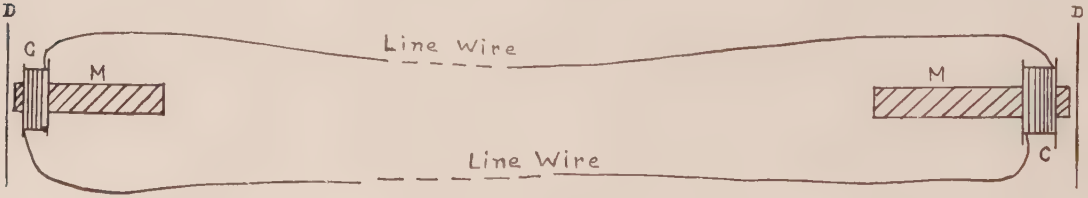
IMPROVEMENTS IN THIS SIMPLE TELEPHONE

The principle of the telephone in your house is the same as that of this simple one which you might make, but before Bell's first instrument could become of great public use several additions and improvements were necessary. Let us get to an understanding of the mechanism of the modern telephone by studying out these improvements before we run through the story of what happens when you lift your receiver.

First, in the original telephone the sounds were carried, but they were not distinct and clear as they are now. To remedy this a special "transmitter" has been invented. Then there must be some signaling or calling device. Lastly, as a network of telephones spreads over a city, there must be a central exchange where one person's line can be connected with that of another.

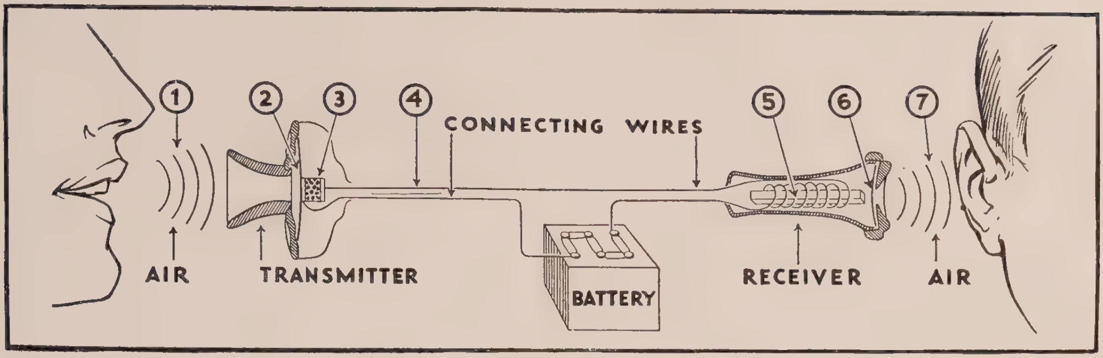
THE BLAKE TRANSMITTER

The first of these improvements was the Blake transmitter, so named after its inventor. Blake saw that the little electric "pulse beats" were actually minute variations in the resistance, resistance being the opposition or difficulty which a current meets in making its circuit. If at some point of a circuit the wires should be broken, the current would meet with great resistance, as it would have to jump across the gap; but if the break were so delicately adjusted that every sound vibration would simply modify the extent of the break, then it would be possible for the voice to set up variations in the electric current much as in the simple telephone. The



A SIMPLE TELEPHONE LINE

No electric battery is needed here. The current is supplied by the magnets.



Courtesy American Telephone & Telegraph Co.

TELEPHONE CIRCUIT USING A BLAKE TRANSMITTER AND A BATTERY

chart above shows the simplest telephone circuit using a Blake transmitter.

The sound-receiving part is somewhat similar to the human ear. The air waves, (1), from the speaker's mouth beat upon the surface of the diaphragm, (2), setting it in vibration. The diaphragm is a flat disk of thin metal free to vibrate in the middle, corresponding to the drum of the ear.

The transmitter of electrical waves is a small box, (3), like a pill box, partly filled with fine grains of hard carbon. This is known as the "button," and is the point in the circuit at which variations in resistance are created. The back of the button, or the pill box proper, is firmly attached to the frame of the instrument and cannot vibrate. The front of the button, or the pill-box cover, is attached to the middle of the diaphragm and vibrates with it. This alternately presses the carbon granules together very slightly and then relieves the pressure.

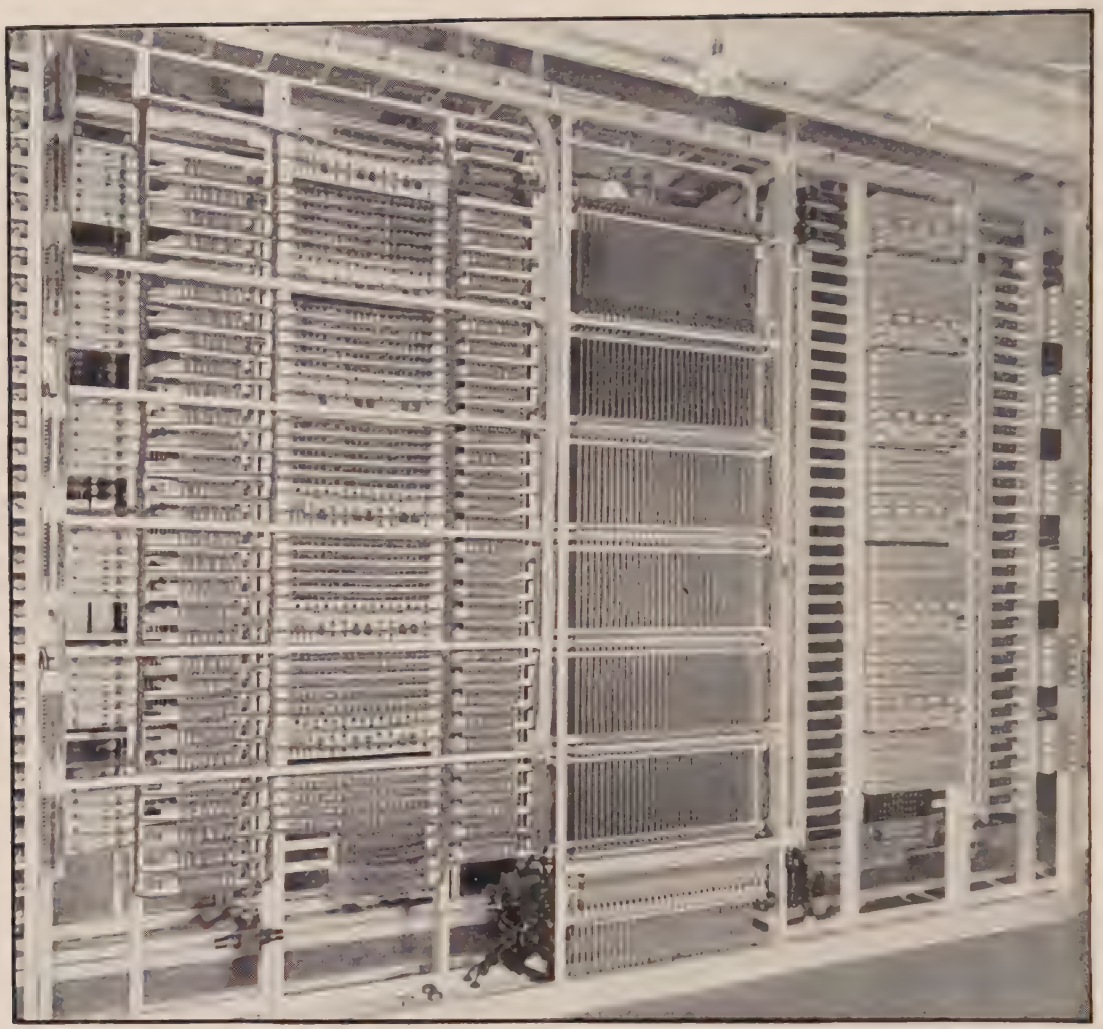
In this instrument the current is supplied by a battery. The two wires of the circuit are connected respectively to the front and back of the button, and the current must flow through the carbon granules. As the carbon is poured in loosely and the grains touch each other but lightly, the electrical path is somewhat broken and not a very easy one to travel. Therefore the current which flows is less than it would be if there were a good solid connection. If the disk is pushed inward, however, the grains of carbon will be pressed together and the current will flow more freely. This is just what happens when one speaks into the receiver; that is, the button cover vibrates and the strength of the current varies accordingly. Thus electrical waves are sent out over the wires.

The vibration of the disk is very much less than a thousandth of an inch at most, and the rapidity of its vibration varies from 200 to 3,000 movements per second. Is it not marvelous that this little box of carbon granules should be able to translate sound waves into electrical waves so faithfully that when translated back into sound waves again in a telephone receiver, perhaps hundreds of miles away, they may be recognized as the voice of a friend?

THE RECEIVER

The telephone receiver is an electric mouth which can utter human sounds. There is a thin diaphragm of iron, indicated in the chart by the numeral 6, and a coil of wire wound on the magnet indicated by the numeral 5. The magnet attracts the iron diaphragm, bowing it slightly toward itself. The stronger the magnet pulls, the more the iron bows toward it, but if the pull decreases the iron flies back, like the bottom of a pan which you are bending with your fingers.

When the electrical waves from the distant transmitter flow through the turns of wire which form the coils about the magnet, they affect its pull upon the iron diaphragm. When the current is stronger the magnet pulls harder and when the current weakens the bent diaphragm springs back. Thus the motion of the diaphragm of the receiver is just the same as that of the diaphragm of the distant transmitter. The air molecules, (7), near the receiver are set



Courtesy: Bell Telephone News

SELECTOR FRAME OF AN AUTOMATIC DIAL TELEPHONE EXCHANGE

into the same kind of motion as those which danced against the transmitter diaphragm. That is why the receiver speaks the same words that were spoken into the transmitter many miles away.

THE TELEPHONE CENTRAL OFFICE

Many of our cities have so many telephone users that the telephone company divides a city into sections, each with several thousand subscribers. Each section is a telephone city, with a convenient name like "Market" or "Canal," and its own central office from which there are wires to each telephone in that section. When you telephone to someone in the same telephone city as yourself your telephone wires are connected at the central office to those leading to the other person's telephone.

The metropolitan area of New York City is divided into more than a hundred and fifty telephone cities, each with its central office. In the lower part of Manhattan Island, the financial center of the world, with its tall buildings, each holding thousands of persons, there are a half dozen of these telephone offices. Each serves about ten thousand subscribers; and yet in this part of the city the number of telephones is so great that central offices may be only a few blocks apart.

When you telephone to someone in another telephone city your line must be connected at your central office to a highway, or trunk line, which leads to the central office in the other telephone city. There the highway is connected to the wires which go directly to the other person's telephone. Tens of thousands of miles of such trunk lines interconnect the various central offices of a large city, for there always must be enough wires so that, without waiting for a telephone highway to be free, a telephone call can go right up to a subscriber's private telephone door and find out if he is busy.

The line of a telephone subscriber is like a hallway leading from the house, or office, where he has his telephone instrument, to the central office of his telephone city. And there he has a door opening onto all the national highways of speech. Through this telephone door and along the hallway, formed by the wires which connect his instrument to the central office, conversation can take place with anyone else who also has a door on the national highway.

For every conversation two telephone doors must be opened, yours and that of the person whom you are calling. If the call starts from a dial telephone the doors are opened, that is, the connections are made, by ingeniously-designed electrical equipment. Otherwise they are opened by girl operators.

At the central office your hallway is closed by a number of doors, all alike except for the one through which your operator answers. This is the door through which conversations pass when you are calling someone else. When you are being called one of the other doors is used. Of these there are enough so that any operator may reach you without delay or inconvenience.

For the telephone calls which you make there is a door directly in front of the operator who gives you telephone service. Beside it is a small electric lamp; this lights and attracts her attention when you take your receiver off its hook. In front of her are several short lengths of paired wire—cords, as they are called. Each is a flexible hallway with which she can connect you to a speech highway or directly to the hallway of anyone who is in your telephone city. A telephone cord is shaped at each end like a plug to fit into the doors, or jacks as they are called.

The operator wears her telephone set. This leaves her hands free to handle the cords and some special telephone "doorknobs" before her. Her own telephone connects with all of the cords; but it is shut off from each cord by a separate door which she controls by a "knob" on the desk in front of her. All these doors remain tightly closed unless she holds one open by its knob, or "listening key," as she calls it. When she sees the light beside your telephone door she picks up a cord and plugs one end of it into the door. Automatically the light goes out. With her other hand she then opens the door which connects her telephone with the cord she is using and so is able to answer you.

Suppose you wish to talk to someone in your own telephone city. Every subscriber in that city has a door within reach of your operator. These doors are arranged in numerical order on a panel in front of her. It takes her only an instant to plug the other end of the cord into the proper door and send a ring down that hallway to call the other person to his telephone. A signal lamp, close to the cord the operator is using, lights when she plugs into the telephone door of the person you are calling. It stays lighted until he takes his receiver off its hook; so she knows at a glance whether or not he has answered your call.

If the telephone you are calling is busy, the operator must know it to avoid interrupting. Special devices help her. She tries his telephone door before opening it. With the tip of the plug she touches the jack. If his receiver is off the hook, because his private telephone hallway is busy, she knows it instantly, for she hears a little clicking sound in her telephone. If she doesn't hear this warning, she pushes the plug all the way into the door and rings to call him.

If the person whom you are calling is in another telephone city your talk must follow a trunk line to the other telephone city. So your operator tests the trunks to the particular telephone city until she finds one that is not in use. Then she inserts the plug into this door. In a moment a sound tells her that the operator at the other end of the trunk in the distant telephone city is ready to make the connection. Then your operator gives the number and the distant operator connects the trunk with the line of the person you are calling.

THE DIAL TELEPHONE

Similar operations must be performed by electrical equipment if your call starts from a dial telephone. This equipment is very complex; that is, it has a great many parts. The parts themselves really are simple mechanisms; and the complexity comes from the large number of telephone lines which the equipment must be able to handle and from the wide variety of operations which it must perform. In the first place, for example, the equipment must find your telephone line when you lift your receiver, picking out your line from the thousands of others which end in the same office.

You remember how the operator does this when the switchboard is manual instead of mechanical in its operation. She is guided to your line by a lamp which lights as your receiver is raised. The electrical mechanism, having no eyes, would not be aided by a lamp; it must hunt in the dark; and it does so by feeling electrically. When your receiver is raised the switch in your telephone set is closed, and current flows along your line from a large battery at the central office. At that office a switching mechanism is set into motion by this sudden flow of current. The mechanism starts sliding over the terminals of a small group of lines among which is yours. It runs along until it feels a line with current in it; then it stops and is ready to do what you want; in that regard it acts like an operator on a manual board.

The girl operator would ask you "Number please?" The mechanism cannot talk, so it sends you a musical tone to say it is ready for your instructions. And since it cannot hear, you dial the number. As the dial swings back there is a click for each unit of the digit you dialed. With each click a pulse of current passes through some electromagnet in the mechanism at the central office. That mechanism then proceeds to put the call through for you. Each of its actions is simple, but taken all together they are very complicated, and a very large amount of equipment is needed.

SENDING PICTURES BY WIRE OR RADIO

The inventor of the telephone might have smiled at the prediction that some day pictures would be sent over telephone wires. Yet this seemingly miraculous feat is now being done as a matter of everyday business.

Nearly anything that can be photographed can be transmitted by wire. Just think of being able to send a picture, a signature, a printed page, or a finger print almost instantaneously to someone a hundred or a thousand miles away. Yet a post-card size photograph can be sent to any point in about seven minutes.

The picture to be transmitted is printed on a celluloid film, similar to the one used in your camera, which is wrapped around a transparent cylinder. Inside the cylinder is a photo-electric cell, a sort of vacuum tube which can vary the strength of an electric current according to variations in the brightness of a light which shines upon it.

A point of light is focussed on the transmitting cylinder, and passes through the film to the photo-electric cell. The cylinder turns slowly and moves along a little at the same time, so that the point of light gradually traces its way over the entire surface of the picture. More or less light is allowed to pass according to the shading of the film, which causes more or less current to pass through the photo-electric cell. This causes small electrical vibrations, which are amplified and sent over the wires to the receiving station.

There a sensitized celluloid film is wrapped about a receiving cylinder, which is moving at exactly the same speed as the cylinder at the sending station. A beam of light from a lamp passes through a light-valve and strikes the sensitive film. This valve is operated by the electrical vibrations coming over the wire, and allows varying amounts of light to reach the film. As the light makes its way across the film it reproduces every detail of the picture being sent. The "exposed" film is developed as in photography, then prints are made on photographic paper which are identical with the original picture miles away.

A similar method is also applied for the transmission of pictures by radio or telegraph.

Much of the material for this article on the telephone is taken from "The Magic of Communication," by John Mills, a very interesting booklet which the Bell Telephone Company of your neighborhood will send you on request.

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MARCONI, INVENTOR OF WIRELESS TELEGRAPHY

THE STORY OF RADIO

THE ends of the earth only half a second apart — that is the story of radio condensed into ten words. Of the "why" and "wherefore" of it, of the "how" and "when" of it, we shall speak in a moment. But the fact itself should first have its chance to grip our imaginations. Think how far apart the ends of the earth have been! how explorers and traders have sailed weary months and years with no news from home, no means of reporting their location or condition to the anxious watchers in the home lands! Think of those gallant missionaries of not more than a hundred years ago who bade farewell to the ship that brought them to some lonely Pacific island, knowing that it would be a full year before that vessel could possibly return with letters and newspapers from the land which they had left, and that when the news did reach them it would be six months old!

Compare this with the amazing situation in which Rear Admiral Byrd has found himself, separated from the populated areas of the world by hundreds of miles, in a region almost unattainable because of barriers of ice and snow, and yet able not only to report daily his experiences to listeners all over the globe, but also to get intimate and official messages from home.

The story of the progress of the world might be written in the terms of its means of communication from the days of watch fires on the mountains and of runners from village to village to the days of the written and the printed word. The tale would progress slowly with only moderate gains until the nineteenth century. Then would come the postal system, which brings every country of the globe within the reach of a letter with a five-cent stamp. Parallel in time with this wonderful gain would be the telegraph and cable systems of the globe, with millions of wires wrapped about the earth, carrying the code messages of dots and dashes which could be quickly translated into words. Our fathers and mothers thought themselves blessed beyond measure to be living in the age of the telephone, when codes and signs could be put aside and the actual sound of the human voice could be carried on wires from one end of a continent to another. Men will be living for many years to come who remember vividly the first uses of the telephone.

And then, almost overnight, as it seemed to the onlooker, came the marvel of communication without wires, the sending of messages through space. In a very real sense we of this particular period are seeing radio as no other generation in the world's history can ever see it. Everyone except our boys and girls has lived in a world where there was no wireless communication, where such a feat as having our messages leap instantaneously from spot to spot was unheard of. Radio jumped into everyday use with a rapidity never equalled in the practical application of any discovery during the world's history. Unknown in one year, the radio set became the tool and the toy of the civilized world in the next year. The men who did the first work with so-called "wireless" are not old men. Yet they with the rest of the world can sit in their homes and hear statesmen speak to them from overseas; they can pick up news by radio as they ride in their luxuriously equipped automobiles or airplanes.

Our children take this talking without wires for granted. Even as the telephone is now a necessary and accepted convenience, so the bringing of distant corners of the earth into instantaneous communication seems so natural as to be commonplace. Only to us of this generation can the marvel, the miracle of radio, come home with full force. We have the background of having lived when it was unknown, and the foreground of its present widespread use. We can use both experience and imagination to look into the immediate and more distant future to see what a change in the world's development this new discovery will make.

THE THEORY OF RADIO

To those of us who have followed in these volumes the simple story of light and heat, the theory of radio need present no difficulties. In the story of "Air and Ether Messages," Volume I, pages 95–112, we learned that heat and light come to us in waves through the invisible ether which, it is assumed by science, probably fills all space. Waves set up in a vast ocean of ether by the sun and stars travel to us and make upon our bodies, our receiving apparatus, the effects which we translate into terms of light and heat. We learned of wave lengths how waves follow each other in processions but at different rates, with more space between the crests of certain types of waves than between the crests of other types. By wave length is meant the distance between two successive waves, the only difference in ether waves being in the rate at which they are made. All this is by way of review of our knowledge concerning these ether waves which we now meet again in connection with the subject of radio.

Radio, or "wireless," is man's control of electromagnetic waves in the ether. Light and heat are both electromagnetic waves; the only difference is in the length of the waves. Radio is exactly the same thing as light and heat. But while the wave lengths of light and heat are so short as to have measurements of only a fifty-thousandth and a ten-thousandth of an inch, respectively, the wave lengths used in radio communication are very long, perhaps from fifty or sixty feet to twenty miles. Such waves have been traveling about in space for all time. Disturbances in the ether which sent out waves of this length have been happening, unknown to or unmeasured by man, for countless ages. Only recently has man detected them and learned how to create and use them for his purposes of communication.

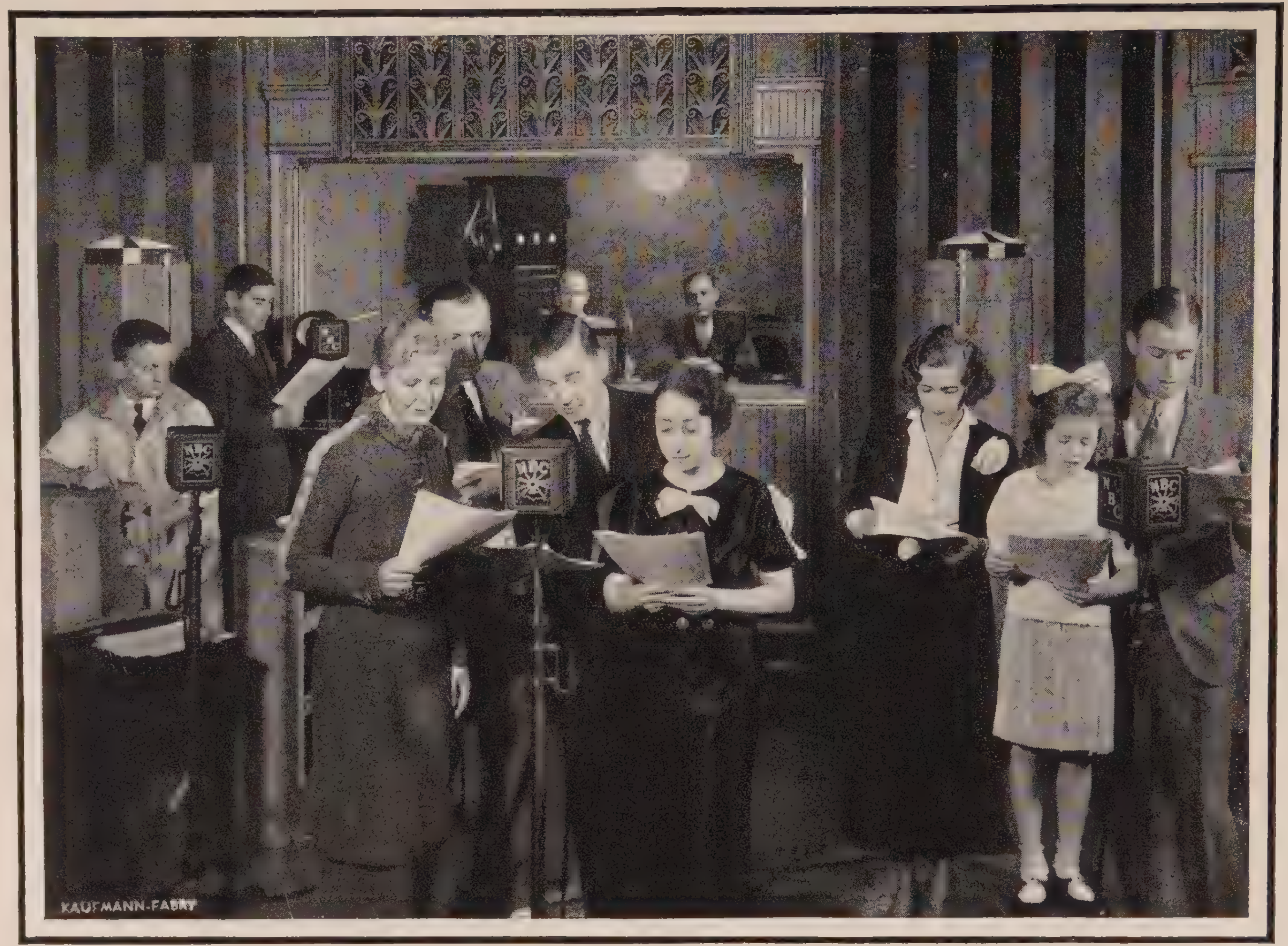
NBC Photo

"RADIO CITY" IN NEW YORK

Circled in the center foreground is the NBC studio. Offices are in the tower building.

THE FIRST USE OF WIRELESS BY MAN

The idea that communication without wires could be accomplished was first conceived in 1864 by James Clerk-Maxwell, an English physicist. He based his conclusions upon mathematical reasoning, which in turn was based upon certain assumptions. If his assumptions were correct, he knew that his conclusions were correct. When his theory was published, in 1865, its truth was doubted by most of the scientists of the time. In 1888, however, Maxwell's theories were actually verified by Heinrich Hertz, the distinguished physicist,



Courtesy of the National Broadcasting Company

INTERIOR OF A MODERN BROADCASTING STUDIO

At the extreme left is the sound effects man; behind him the announcer. The others in the foreground are the members of the cast of a dramatic serial radio production. Seated in the control room behind the sound-proof glass window are the two control engineers who govern volume and clarity and blend the sounds coming from the several microphones into one harmonious whole.

by means of a series of brilliant experiments. Maxwell suggested that electric currents vibrating at an extremely rapid rate would send out electric waves. Hertz actually produced and detected these waves. In his honor they were called "Hertzian waves."

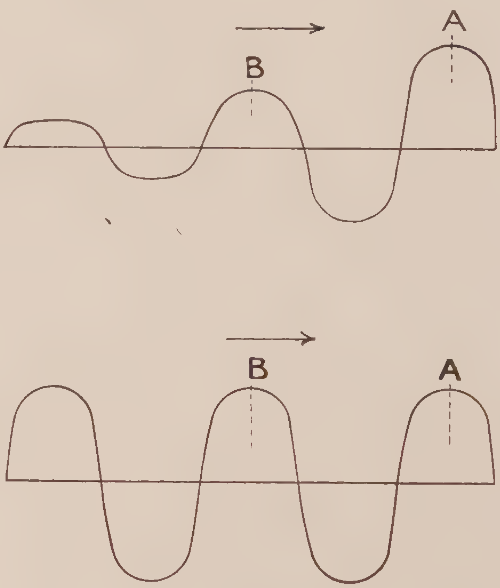
Guglielmo Marconi succeeded in applying these electric waves for the transmission of signals through space, and is therefore often termed the inventor of wireless telegraphy. His experiments near Bologna, Italy, were so successful that he filed application for a patent (in Great Britain) on June 2, 1896. After extensive preliminary demonstrations by Marconi in England, Theodore Roosevelt sent a message to the King of England. This famous message was sent from the Marconi station at Wellfleet, Cape Cod, Massachusetts, and was received at Poldhu, England, on January 19, 1903.

HOW ELECTRIC WAVES TRAVEL

Electric waves travel out from a transmitting station in much the same way that water waves travel out from the point where a stone strikes the surface of a pond. Such a water wave, sent out by the splash produced by the stone, can be detected at some distance from its source. The simplest detector would be a cork, which would move up and down as the waves passed. If we were unable to see, we could readily feel the passing of these waves were we to tie a string to the cork and hold it lightly between our fingers. This is the form of wave sent out by a "spark transmitter," which was the kind of transmitter first used in wireless communication. When you dropped the stone in the water, you may have noticed that the very first wave ring, or crest, which moved outward was the largest, and that each succeeding one was smaller, as illustrated. This is known as a "damped wave." Because of the difficulty of keeping waves of this type within legal limits of wave-length, the law now forbids the use of spark transmitters, and we find another form of wave in use, known as the "continuous wave." If, instead of dropping the stone in the water we had moved a disc up and down on the surface, a ring would have left our model transmitting station once for every downward or upward movement of the disc. Thus all crests would have been of the same size and height. These are "continuous" or "undamped waves." All radio communication, telegraphy and telephony, is now carried on by use of continuous wave transmitters.

CONTINUOUS WAVE TRANSMITTERS

The spark transmitter produced a splash in space. Its wave length could not be accurately controlled, and when radio stations began to become more frequent much confusion was caused by interference between the waves of various transmitters. Legislation was finally passed against them, allowing only transmitters of the continuous wave variety. These transmitters are much more efficient and produce a pure vibration which will only react upon a receiving circuit which is very exactly "tuned." By tuning, we mean that a receiving set is adjusted so that it will give a maximum response for a particular incoming wave.



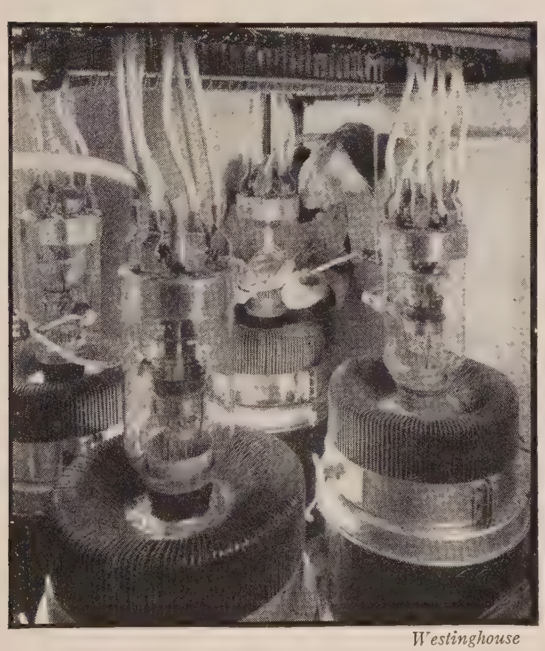
THE TWO TYPES OF WAVES

Above: Damped waves, where the first crest is the highest. Below: Continuous waves, where all the crests are of the same height. A and B are crests of waves; the distance from A to B is one wave length.

The waves sent out into space by a radio transmitter travel at the tremendous rate of 186,000 miles a second, or 300,000,000 meters a second. This means that if a radio station is broadcasting on a 300 meter wave length, which is near the middle of the standard broadcast range, the rate of vibration is one million vibrations per second. Radio men call 1,000 vibrations a "kilocycle" and would speak of that station as broadcasting on a frequency of 1,000 kilocycles. Short wave broadcasting uses wave lengths as short as 16 meters which means frequencies of more than 18,000 kilocycles. Various means have been used to generate the high-frequency continuous waves required in radio. The first regular communication across the Atlantic was made possible by a high-frequency generator designed by E. F. W. Alexanderson and known as the Alexanderson alternator. Another device is the Poulson arc, so called because Valdemar Poulson, a Danish inventor, was first to develop a method of using the electric arc as a generator of high-frequency vibrations.

THE VACUUM TUBE

But by far the most common method of generating radio waves is by means of the thermionic valve or, as it is generally called, the vacuum tube, the most versatile of all electrical devices. This little device consists of three metallic elements sealed into a glass tube from which practically all the air has been removed. One element of the tube, called the "filament," gives off little carriers of electricity when it becomes heated to the proper degree. (These little carriers are "electrons," and their story is told in "Worlds Within Worlds," Volume X, page 317.) These marvelous vacuum tubes can be used for transmitting, for receiving, and for the magnification or amplification of signals.



Westinghouse

GIANT TRANSMITTER TUBES

These huge air-cooled tubes give off so much heat that the air used to cool them is also used to heat the building.

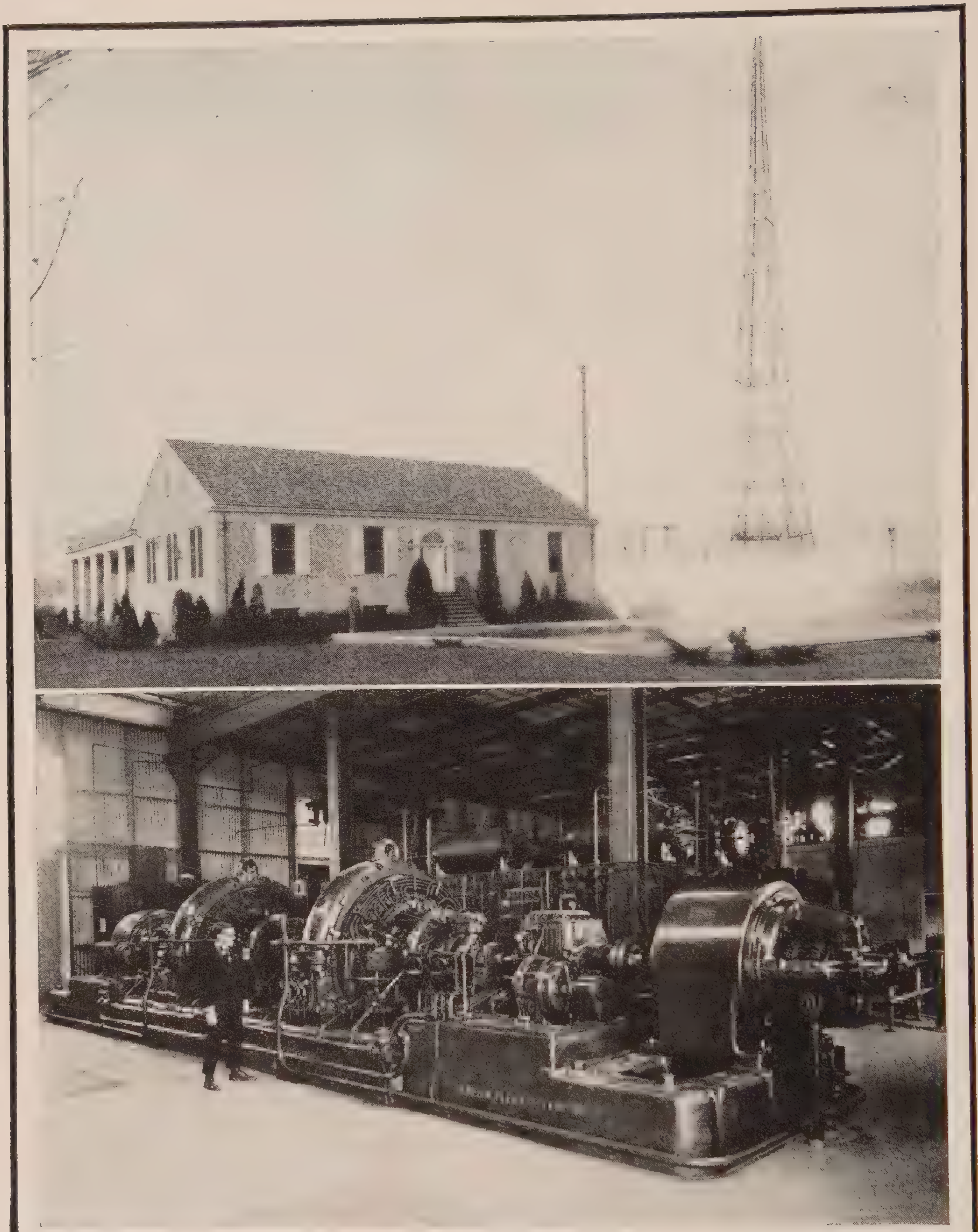
NBC Photo

THE MAIN CONTROL DESK OF A BROADCASTING SYSTEM

The lights represent the different stations on the coast-to-coast network, which the operator controls.

THE RECEIVING SET

Space does not allow for a thorough description of the receiving set and how it operates, and we must confine ourselves to speaking of it in its simplest form. First, there is the "aërial" or "antenna" to catch the incoming electric waves. This is connected to a "tuning condenser." Next comes the "radio frequency amplifier"; then the "detector"; and last the "audio frequency amplifier" which is the final apparatus through which the electric current passes before acting upon the headphones or loud speaker. Let us trace an incom-

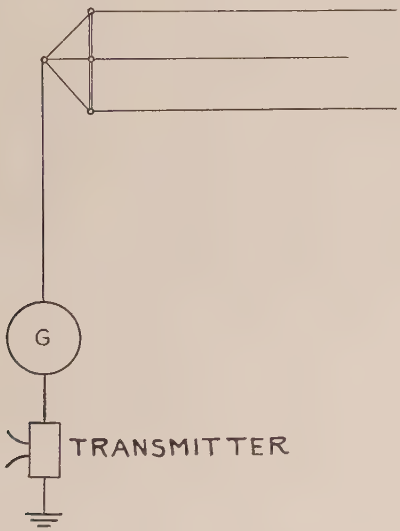


Photos, Top NBC; Bottom RCA

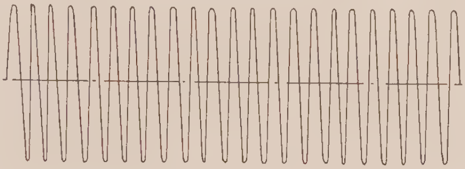
TOP: TRANSMITTING PLANT OF STATION WJZ AT BOUNDBROOK, NEW JERSEY. BOTTOM: THE FAMOUS ALEXANDERSON ALTERNATOR WHICH MADE TRANS-OCEANIC COMMUNICATION POSSIBLE ing signal. An electric wave strikes the antenna and produces in it a vibrating current. By proper adjustment of the tuning condenser this current is received at its maximum strength. The radio frequency amplifier magnifies these waves, but they are still vibrations of the extremely high rate at which they were sent out by the sending station, too rapid to be heard by the human ear. The detector translates this wave into a vibration at a lower rate which we can readily hear. Thus it becomes an audible or an "audio" wave. This audible wave can be still further magnified by the use of the audio frequency amplifier, and can be built up through several stages to the point where it is powerful enough to be heard in the loud speaker.

RADIO TELEPHONY

Radio telephony was made possible by the continuous wave. Because of the dying out of the damped waves produced by spark transmission, they cannot be used as carriers of the voice. Continuous waves can be sent out which have been molded by the effects of speech, and they can then be received by any receiving set.

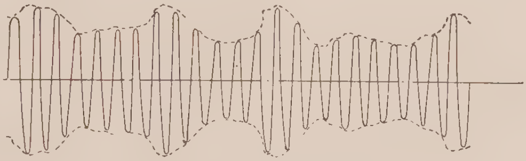


If a continuous wave generator is connected in the antenna circuit, in which a sort of telephone transmitter is also connected, there will be a continuous wave of constant strength so long as the transmitter is not spoken into. Speaking into the transmitter, however, varies the strength of the electrical resistance of the antenna circuit, causing an effect similar to that of which we have spoken in discussing the telephone in the earlier part of our section on "Electricity." The continuous wave is called the "carrier wave." Traveling as it does at the rate of hundreds of millions of vibrations a second, it is molded or "modulated" by the vibrations of the voice, which average only about 800 a second. The voice-modulated wave is therefore sent out from the transmitter and picked up by the receiving station. The detector of your receiving set has the peculiar property of slicing off the lower half of the irregular wave and sends to the phones or loud speaker currents which vary in exactly the same way as the original voice. These currents produce a reproduction of what is spoken into the transmitter. This, in brief form, is the process which has made radio telephony and broadcasting possible.



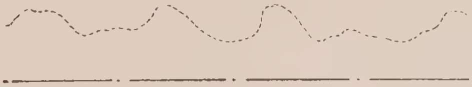
WAVE SENT OUT INTO SPACE

When transmitter is undisturbed.



MOLDED OR MODULATED WAVE

Sent out when transmitter is spoken into.



RECEIVER CURRENT

After detector has cut off lower part of the molded wave.

BROADCASTING

Following Marconi's discovery, the perfecting of radio instruments and the setting up of commercial and government wireless telegraph stations were gradually accomplished for a period of two decades or so. Before the year 1914 there were several transoceanic stations in operation, and a year later the American Telephone and Telegraph Company, working with the Western Electric Company, managed to transmit the human voice from Washington to Paris, a distance of thirty-seven hundred miles. Within the year the distance of five thousand miles, from Washington to Hawaii, was covered. These were spectacular feats of communication in their day.

Intense public interest in radio dates from the year 1921, when broadcasting from the radio telephone was begun at Pittsburgh, Pennsylvania. Broadcasting had been attempted before but without conspicuous success. Two inventors who were with the Westinghouse Company, R. C. Rypinski and Frank Conrad, were able to make this public service feasible for popular use.

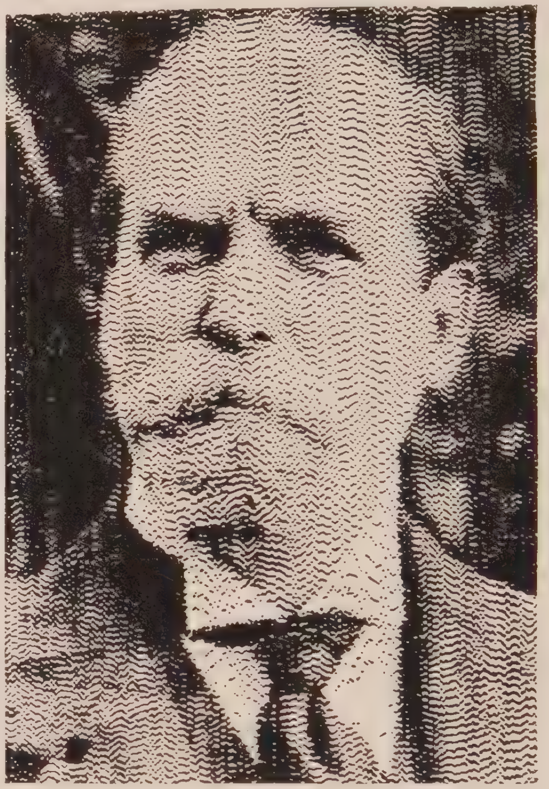
THE GROWTH OF BROADCASTING

The honor of having broadcast the first regular radio programs belongs to station KDKA of Pittsburgh. But other stations followed rapidly and within a few years several hundred broadcasting stations were built in the United States alone. Meanwhile millions of receiving sets were being built and sold. In 1926, only five years after the first broadcast, there were radio sets in more than five million homes in the United States. In 1930 this number had increased to twelve million and in 1940 to nearly thirty million.

Today many programs come to us over "network" systems maintained by great broadcasting companies. A program given in a central studio is carried over telephone wires to a number of widely scattered radio stations from which it is sent into the air. By this means important events have been broadcast from seventy or more different stations at the same time, reaching listeners in every corner of the country.

Since the discovery that signals on short wavelengths have unusual carrying power, many broadcasting stations also send out their programs over the short waves. American programs are enjoyed on several continents, while American listeners are able to hear broadcasts originating in Europe, South America and other far off lands.

Also, since January 1, 1941, certain stations have been sending out programs by a method known as frequency modulation, or FM. As explained on page 89, the older method of broadcasting modulates the strength of the signal; FM broadcasting modulates the frequency or wavelength of the signal. The advantages of FM are freedom from static and very full true tone. The disadvantages are that the programs cannot be sent over long distances and that specially designed receiving sets are necessary.



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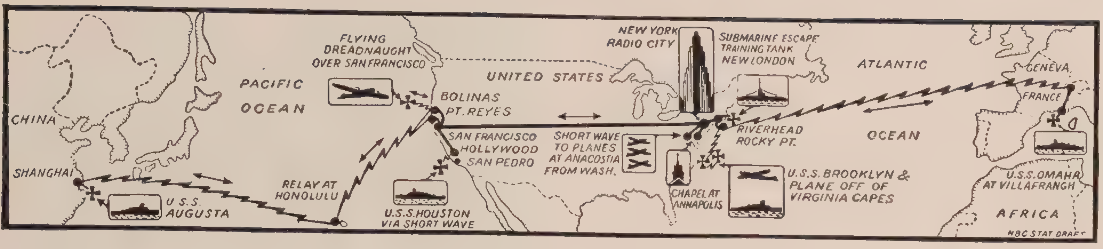
ONE OF THE FIRST PHOTOGRAPHS SENT BY RADIO
In 1924 this photograph of Mr. Hughes, then Secretary of State, was sent across the ocean in twenty minutes.


FLYING DREADNAUGHT OVER SAN FRANCISCO
NEW YORK RADIO CITY
SUBMARINE ESCAPE TRAINING TANK NEW LONDON
ATLANTIC
GENEVA
PACIFIC
OCEAN
UNITED STATES
BOLINAS PT. REYES
FRANCE
CHINA
SAN FRANCISCO HOLLYWOOD SAN PEDRO
SHORT WAVE TO PLANES AT ANACOSTIA FROM WASH.
RIVERHEAD ROCKY PT.
OCEAN
SHANGHAI
RELAY AT HONOLULU
U.S.S. AUGUSTA
U.S.S. HOUSTON VIA SHORT WAVE
CHAPEL AT ANNAPOLIS
U.S.S. BROOKLYN & PLANE OFF OF VIRGINIA CAPES
U.S.S. OMAHA AT VILLAFRANGH
AFRICA
NBC STAT DRAF

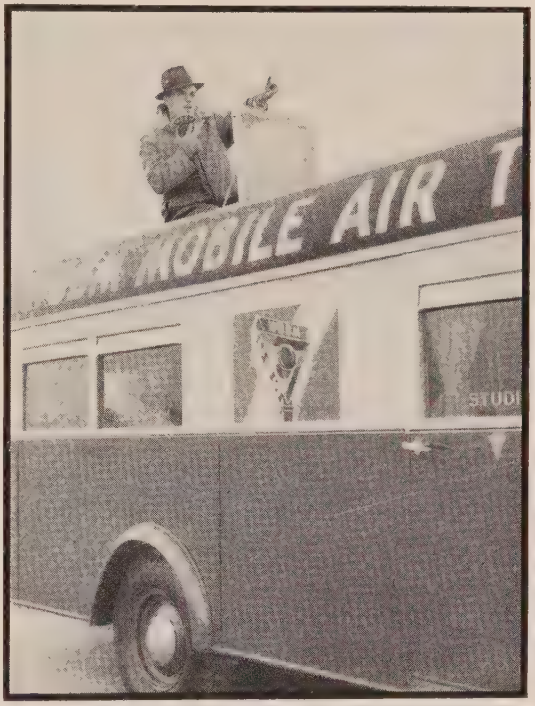
NBC Photo

HOW RADIO BRINGS THE WORLD TO OUR EARS

On one Navy Day program, American listeners heard messages from China, from France, from ships in the Atlantic and in the Pacific and from planes in the air.

Radio came into widespread use very rapidly and soon created national and even international problems concerning the right to broadcast. The number of broadcasting channels or wave-lengths over which radio messages can be sent is limited and the number of broadcasters and would-be broadcasters soon greatly exceeded this limit. Because chaos threatened the industry a national conference of radio experts was held in Washington in 1922. As a result of this conference the federal government undertook the control of radio through the Department of Commerce. Later, under the Radio Act of 1927, the Federal Communications Commission was created. This Commission now controls all commercial and amateur broadcasting in the United States by granting or withholding operating licenses. The Commission also assigns call letters and wave-lengths and allots certain hours to the broadcasters. International conferences were held at Washington in 1927 and at Madrid, Spain, in 1932. These resulted in agreements governing the wave-lengths and code signals to be used by ships at sea, establishing rules for handling international messages, and settling all problems that might affect more than one nation.

It is interesting to note that at the first radio conference Herbert Hoover, then head of the Department of Commerce, championed the cause of the American boy. He emphasized the need for protecting the interests of amateurs. Should they be limited to too small a range of wave lengths or be cut off from the possibility of sending as well as receiving messages over considerable distances, their healthy interest in the art would be discouraged, and a great asset in the national development of radio would be lost. Amateurs, "hams" as they are called, have done remarkable things in radio with equipment so simple and inexpensive that the big commercial radio companies have looked on in astonishment. This is a field in which any operator of inventive turn of mind may find his chance to do something original.



Courtesy, Columbia Broadcasting System

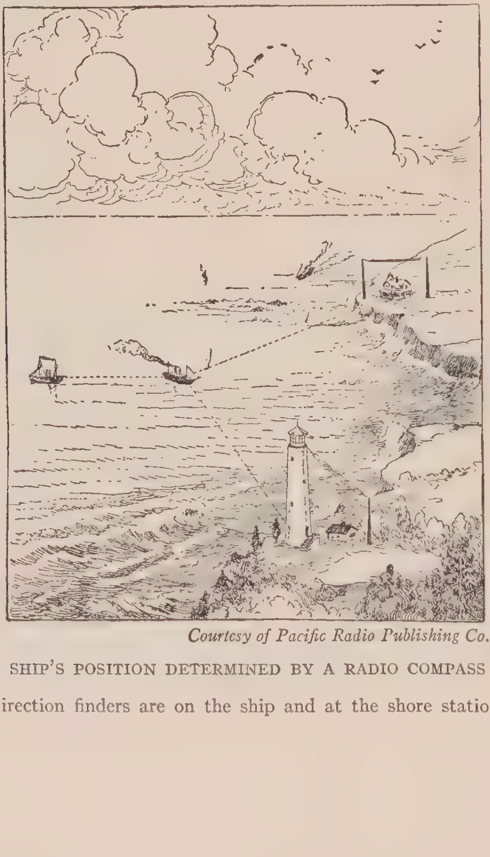
BROADCASTING NEWS WHEN AND WHERE IT HAPPENS

Up through the hatch goes the roving radio reporter to describe a parade, a sporting event, or an airshow from his vantage point atop the radio-equipped trailer. Moving at fifty miles an hour, or standing still, the trailer's short wave transmitter is able to relay the broadcast to the radio station's main transmitter, whence it goes out again in the regular way.

The country is at present divided into districts and every amateur who wishes to set up a transmitting set should apply to the radio inspector of his district for an operator's license. For information as to the districts he should write to the Federal Communications Commission at Washington, D.C.

RADIO COMPASS SERVICE

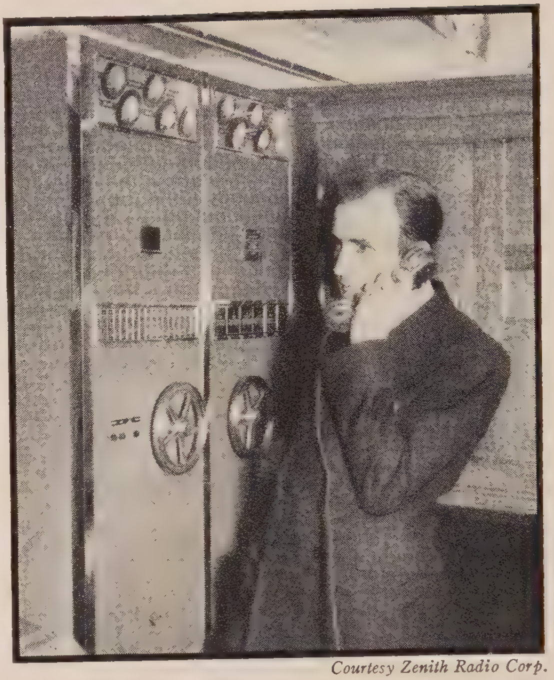
Compass service for ships is an interesting branch of radio. A ship at sea sends out the question, "Where am I?" Suppose this ship is in the Atlantic, fifteen hundred miles off the coast. Boston picks up the question at its naval station and notes the direction from which the inquiry comes. New York gets the same inquiry, but from a different angle. Boston and New York get into touch with each other, compare their findings, and by a simple process of mathematics known as triangulation, are able to determine from what point the signal came. One of the stations then signals the vessel its latitude and longitude. Wireless "lighthouses," so called, have been established along the coasts which send out, at intervals as regular as the flashing of a light, signals which are received by radio operators on ships at sea. The ship's operator can identify two stations by their own special signals, note the direction from which the signals come and then, by drawing on a chart two lines leading out from those stations in the directions he has determined, locate his ship at the point where the two lines cross.



Courtesy of Pacific Radio Publishing Co.

SHIP'S POSITION DETERMINED BY A RADIO COMPASS

Direction finders are on the ship and at the shore stations.



Courtesy Zenith Radio Corp.

SHIP TO SHORE TELEPHONE

Radio telephone calls from ship to ship or from ship to shore are handled in much the same manner as a long distance land call. The person on shipboard merely lifts the receiver and calls his ship's radio telephone operator, giving the city and the number desired. The ship's operator tunes to the wave-length of one of the many shore radio-telephone stations and calls this station just as if he were calling from an ordinary telephone switch-board. From there on, once the station is reached, the call travels over land wires like any long distance call. If a ship is to be called from land the call travels by land wires to the nearest shore radiophone station, and is radiophoned from there to the ship.

TODAY AND TOMORROW

Airplanes also are equipped with radio. The great ships flying on established passenger routes are now in constant communication with their airports. The pilot makes frequent reports by radio telephone, and in return receives weather information and instructions which add greatly to the safety of operation. In clouds or fog, many of these airliners are guided by a "directional" radio beam which automatically transmits signals enabling the pilot to tell the instant he strays from his regular course.

Police and fire departments now call on the radio to aid them in their duty of safeguarding lives and property. Frequent broadcasts from local and state police stations transmit instructions and information to radio-equipped patrol cars. In many communities "two-way" radio is employed, through which patrol cars and stations may talk back and forth to one another. Fire departments send out alarms on their short-wave transmitters, and in coastal cities direct the work of the fireboats by the same means.

Explorers carry short-wave radio sets with them and are thus enabled to keep in touch with the world, and also to report any misfortunes which befall them, so that assistance may be sent.

Photographs are sent by radio, and it has been predicted that motion pictures may soon be transmitted over the air. Already small ships and land vehicles have been controlled by radio,—that is, operated without hands by the directing power of a radio transmitter which does not come into any actual physical contact with them. Airplane patrols with radio equipment are saving millions of dollars by reporting forest fires so promptly that they can be fought before they gain too great headway. So the story might be continued indefinitely.

"Radio," it has been well said,[1] "forms an invisible bond between the nations of the world. Indeed, it is a great and powerful binder of the peoples of the earth."

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[1] The Complete Radio Book. The Century Company.

Copyright, International

AT THE OPENING OF NEW YORK LONDON RADIO-TELEPHONE SERVICE

President Gifford of the American Telephone and Telegraph Company is putting in the first transoceanic call, while a group of officials "listen in." Sir Evelyn Murray, Secretary of the General Post Office of Great Britain, received this call at the other end and replied.

WHAT IS TELEVISION?

TELEVISION means "seeing at a distance." It does for the eye what the telephone and the radio do for the ear; but it is much more difficult to explain. Though a great deal has been done in developing television, and some truly remarkable results have been achieved, television is not yet practical in the way that the radio is practical. The cost is high and the results are limited. However, electric sending of pictures and writing, which is a form of television, is already widely used.

All television is based on the photo-electric cell, which produces an electric current in exact proportion to the amount of light that shines upon it. Now the things we see—or want to see—by television may consist of many different degrees of light and shade. How can we send these out all at the same time?

The answer is, we don't. We break up the picture into hundreds of tiny dots of different brightness, which act upon the photo-electric cell in turn. At the receiving end these dots are put together again and all this is done so quickly that the eye sees an unbroken picture.

THE SCANNING DISK

The sending is done by means of a clever little wheel, invented by P. Nipkow more than fifty years ago. It is called a scanning disk. To scan means to look at something point by point, and this is just what the scanning disk does. It has a number of holes arranged in the form of a spiral around the rim. The disk is so arranged that when it spins a beam of light falling through the holes will be guided like a thin pencil over the picture, person, or scene to be scanned. Each time the disk turns, every point of the picture is covered, one after the other, in far less time than it takes to tell. Remember: the whole scene is not illuminated at once; the light falls on only one tiny dot at a time; but this dot of light, quick as a flash, skips over every part of the picture many times each second.

Every picture reflects light thrown upon it—that is how we see things, for the reflected light enters our eyes. Different parts of a picture reflect more or less light—that is how we distinguish between light and dark. In television the beam of light passing through the scanning disk is reflected from the picture, not directly to the eye of the distant observer, but to a photo-electric cell, which, as you may know, is often called an "electric eye."

RCA Photo

AN EXPERIMENTAL TELEVISION CAMERA USING AN ICONOSCOPE

If you have read carefully up to this point, you will understand that the photo-electric cell receives in quick succession light impressions from every point of the picture to be "televised." These light impulses are stronger or weaker, as the point of the picture from which they come is lighter or darker. As the photo-electric cell turns light into electric current, our cell now produces a current which varies as the light shining on the cell is stronger or weaker. This current can be sent to distant places along wires or by means of radio waves.

THE RECEIVER

At the receiving end the current is picked up in the usual way and made stronger or amplified, as it is called. It is then fed into a certain kind of electric lamp which glows more or less brightly, as the current varies. The lamp shines on a small screen, at which the observer looks, through another scanning disk timed to run at exactly the same speed and in exactly the same way as the one at the sending side. (This is called "synchronization" from two Greek words meaning "together" and "time.") It can and must be done so accurately that the holes in the two disks scan corresponding points at the same instant.

The result is that the observer at each instant sees a tiny part of the screen illuminated just as brightly as was the corresponding part of the original picture. As the scanning takes place so very quickly the eye sees the entire screen illuminated and a moving image of the original scene appears.

This is the essential principle of television on which most present systems are based, though there are many variations. Some of the chief experimenters have been J. L. Baird of England and, in the United States, C. F. Jenkins, E. F. W. Alexanderson, and H. E. Ives.

THE ICONOSCOPE

In order to transmit a television picture that has "high definition" (that is, one in which many and tiny details may be seen) it is necessary that the scanning spot be very small. That this is true may be realized when one thinks how difficult it would be to draw with a crayon the fine lines of a postage stamp engraving.

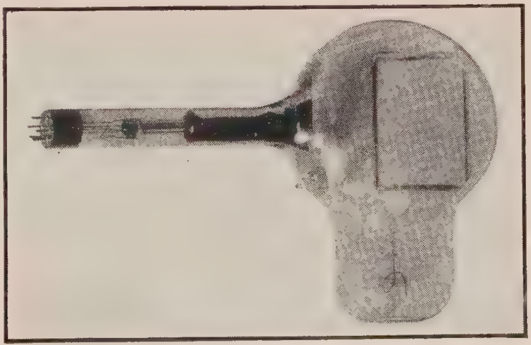
In the scanning disk system this means the holes in the disks must be so very tiny that it is impossible to get enough light through the holes to produce enough photo-electric current at the transmitter to "pick up" the picture or enough at the receiving disk to see the picture without straining the eyes.

Several experimenters have devised systems which accomplish scanning by deflecting streams of electrons (in vacuum) instead of by mechanical means and thereby make higher definition possible. Among these, the "Iconoscope," a pick-up tube of cathode-ray type, invented by V. K. Zworykin, has given excellent results.

Experimenters have been able to transmit pictures about seven inches square which are bright enough to be viewed in a living room even when one or two floor lamps are lighted. The picture cannot be received at great distances due to the peculiar behavior of the very high frequency radio waves which are necessary for the extremely wide radio channel required for television. Then you can realize that a great number of stations would be required to serve a country as large as the United States.

THE FUTURE OF TELEVISION

Many predictions have been made in recent years about television. Time and again we have been told that in a little while it would be in all our homes. These predictions have not as yet come true because to make television possible and available to everyone has turned out to be a task of immense magnitude. Many experimenters, both in the United States and in Europe, are working hard on the problems of television and much progress is being made. Generally, television work has been confined to laboratories and therefore people have not had an opportunity to see a television system in operation. In the sense that the laboratory has supplied us with a basic means of seeing at a distance, it may be said that television is here. But as a system of sight transmission and reception comparable in coverage and service to the present nation-wide system of sound broadcasting, television is not here; it is not yet ready for general service. The all important step that must now be taken is to bring the research results of the scientists and engineers out of the laboratory and into the field. Without a doubt it will be only a question of time before we all shall be able to see at a distance.



RCA Photo

AN EXPERIMENTAL ICONOSCOPE, OR CATHODE RAY TUBE FOR USE IN A TELEVISION CAMERA

U. S. Army Air Service

FOKKER MONOPLANE THAT MADE FIRST NON-STOP TRANSCONTINENTAL FLIGHT

THE INTERNAL-COMBUSTION ENGINE AND WHAT IT HAS MADE POSSIBLE

THE AUTOMOBILE, THE MOTOR BOAT, AND THE AIRSHIP

THE invention and development of the internal-combustion engine opened up to mankind an entirely new and unusually convenient source of power. The steam engine requires a large boiler to supply it with energy. The electric motor needs a power house or bulky storage batteries to provide the current necessary for its operation. In contrast, the internal-combustion engine is a complete power plant in itself. The name "internal-combustion" shows this fact, as it is given because the fuel is burned within the engine itself.

Probably no other source of power is so universally used. Because this type of engine occupies little space, and may be obtained in sizes developing from one to thousands of horse power, it is used in unlimited ways in stationary power plants and furnishes an ideal engine for tractors, automobiles, motor boats, and aircraft.

Before the internal-combustion engine was available, such machines were impossibilities, but their uses have so multiplied that there are now few of us who do not come into daily contact with this engine in some form or other. Perhaps you already operate an automobile or look forward to the day when you will do so. If you live in the country, you may have been called upon to help repair the engine that pumps the water or cuts the ensilage. In any

Courtesy of International Harvester Co.

THE INTERNAL-COMBUSTION ENGINE AT WORK

Upper left: Plowing. Upper right: Making a road. Lower left: Switching freight cars. Lower right: Pumping oil.

event, sooner or later you will find it worth while to know something of how and why the internal-combustion engine works. To give you this useful information is the purpose of the following pages.

HOW THE POWER IS PRODUCED

The internal-combustion engine operates by means of explosions which take place within the engine cylinders. The force of these explosions drives down a piston, which is connected with and turns a crankshaft and flywheel. Such an explosion is only a very rapid burning, or combustion, of the fuel within the engine.

Combustion is the chemical union of a fuel with oxygen (which we find in the air), and gives off heat and sometimes light. It varies greatly in speed, ranging from the slow formation of rust to the explosive burning of gunpowder.

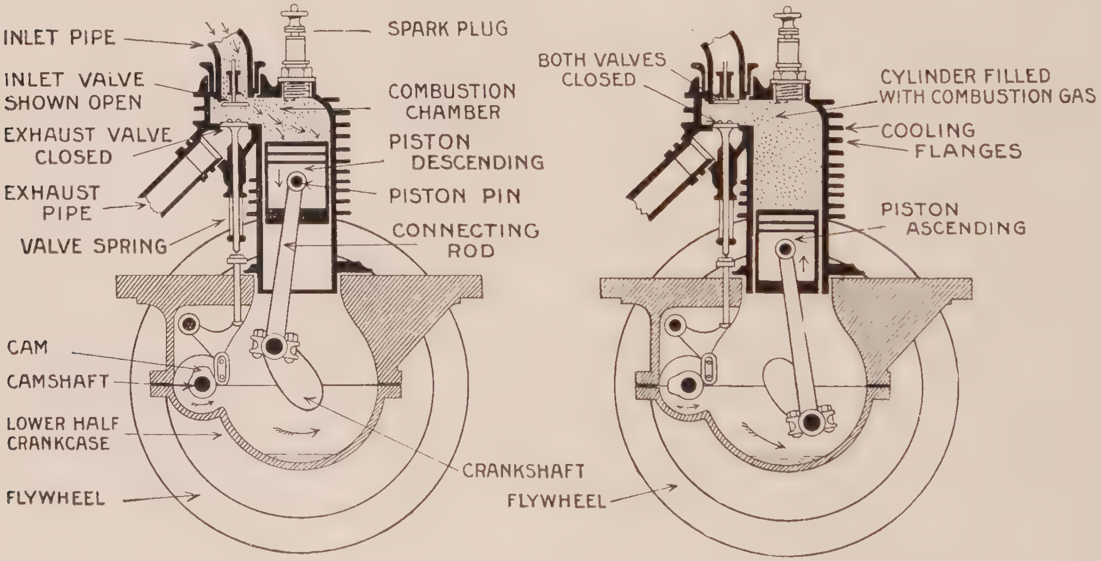
When gasoline or other fuel is mixed with the proper amount of air in the cylinder of an internal-combustion engine and ignited (usually by means of an electric spark), instantaneous combustion results and power is produced.

Illuminating or natural gas, kerosene and other kinds of oil are often used as fuel for stationary engines, but they are not yet suitable for light portable power plants such as those of the motor car or airplane. Gasoline remains the almost perfect fuel for this purpose. It is practically the only one which can be changed to a vapor at ordinary temperatures, and this vaporization must take place before any fuel can be used in such an engine.

DAMAGE FROM UNCONTROLLED EXPLOSION

THE PRINCIPLES ON WHICH THESE ENGINES OPERATE

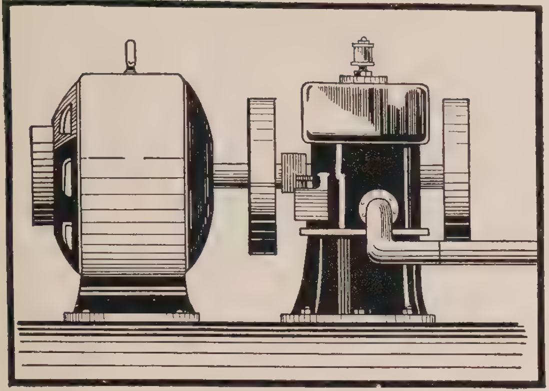
In order for an internal-combustion engine to operate continuously, provision must be



FOUR OPERATIONS WHICH TAKE PLACE

The intake stroke.

The compression stroke.



POWER FROM CONTROLLED EXPLOSION

made for getting a charge of fuel into the cylinder, igniting it, and sweeping away the exhaust gases in preparation for a new charge. This series of operations is called a "cycle." Four operations must take place.

First, the explosive mixture must be drawn into the cylinder of the engine. This is called the "intake" or "suction stroke."

Second, this fuel charge must be compressed to a pressure of about seventy-five pounds to the square inch.

Third, the charge must be ignited by an electric spark, causing an explosion which produces the "expansion" or "working stroke."

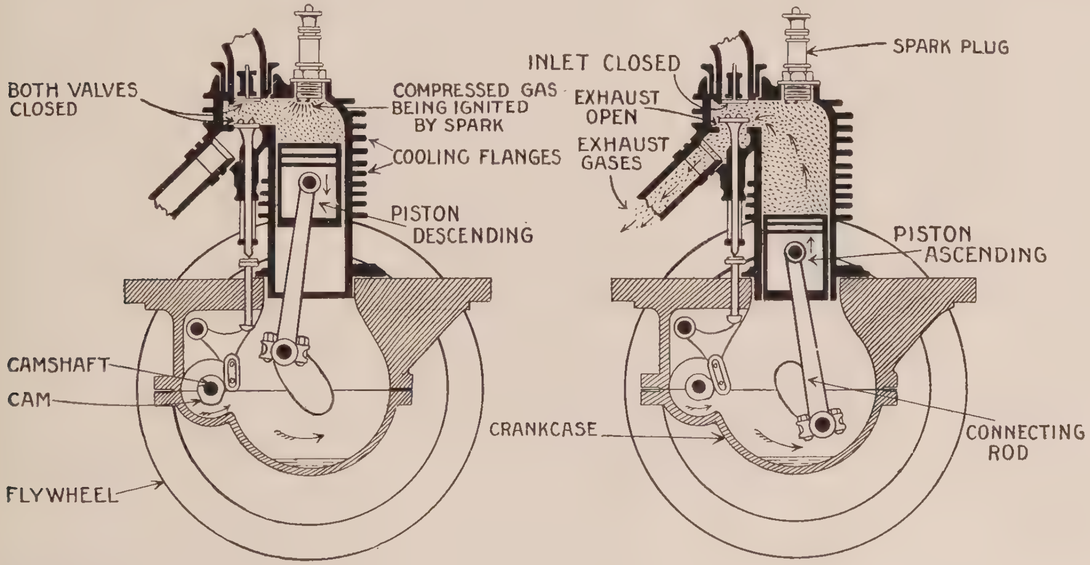
Fourth, the burned gases must be forced from the cylinder to make room for a new charge. This is called the "exhaust stroke."

The two types of engine in common use today operate on either the "two-cycle" or "four-cycle" principles, or more correctly, "two-stroke-cycle" or "four-stroke-cycle."

In the four-cycle, these four events — intake, compression, expansion, and exhaust — occupy four consecutive strokes or two revolutions of the engine. In the two-cycle, these same events take place in two strokes or one revolution. As the latter type is little used except in small stationary engines and motor boats, we need not consider it further. The four operations as they take place in a four-cycle engine are clearly shown in the illustrations below, and are worth your study.

The explosive mixture passes to and from the cylinder through valves; the intake valve admitting the charge, and the exhaust valve allowing the burned gases to pass out. These valves are operated by "cams" on shafts driven by the main engine shaft, which cause the valves to open and close at the proper time.

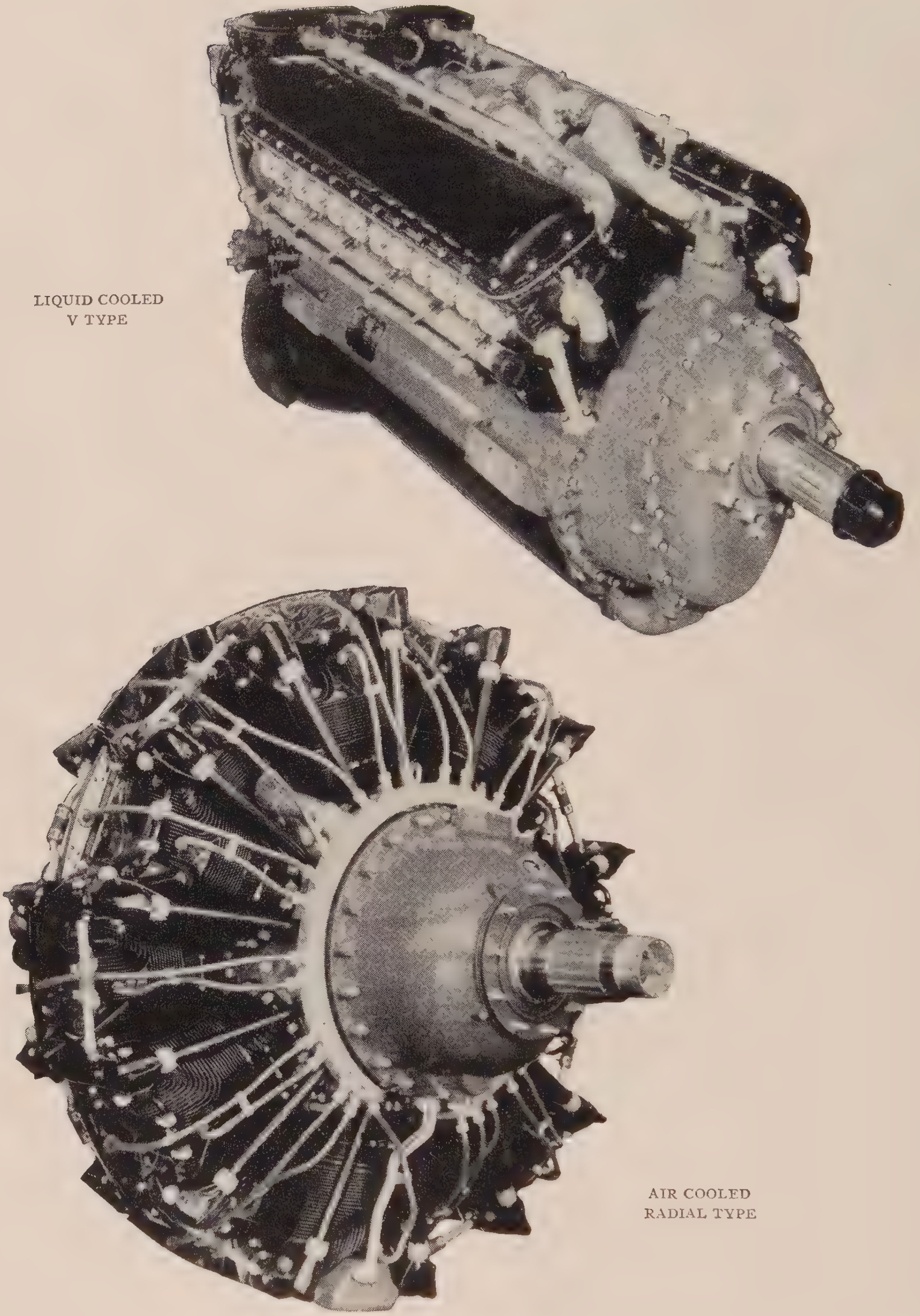
Such valves are known as the "poppet" type, and are almost universally used. The "sleeve" valve, found in a special make of engine, has never gained wide popularity.



IN A FOUR-CYCLE INTERNAL-COMBUSTION ENGINE

The expansion stroke.

The exhaust stroke.

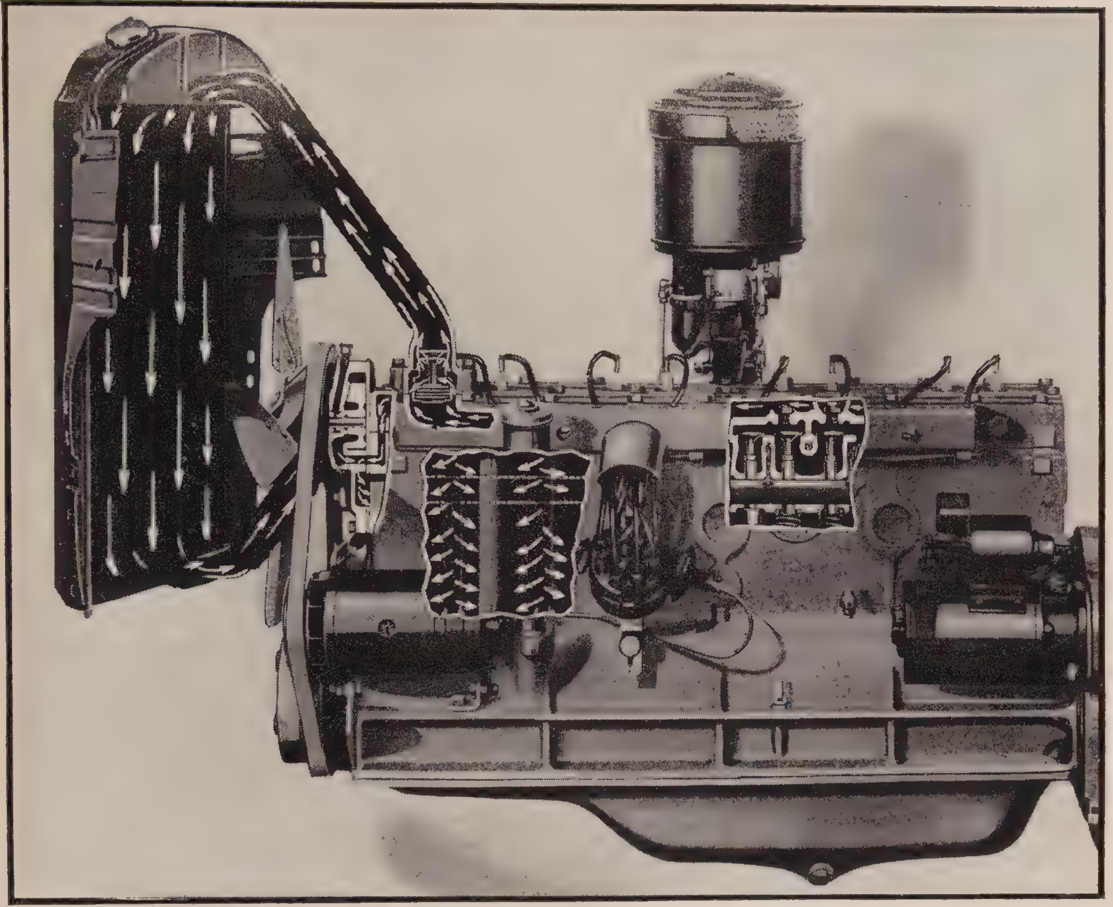


LIQUID COOLED
V TYPE

AIR COOLED
RADIAL TYPE

Courtesy General Motors

TWO TYPES OF AIRCRAFT ENGINES



Courtesy, Pontiac Motor Co.

THE COOLING SYSTEM
The arrows show the circulation of water.

The temperature in the cylinder when the explosion takes place may reach 4500 degrees Fahrenheit. Some means must be provided to carry the heat away, as the cylinder walls would otherwise become too hot, the lubricating oil would burn, and friction would quickly spoil the wearing surfaces.

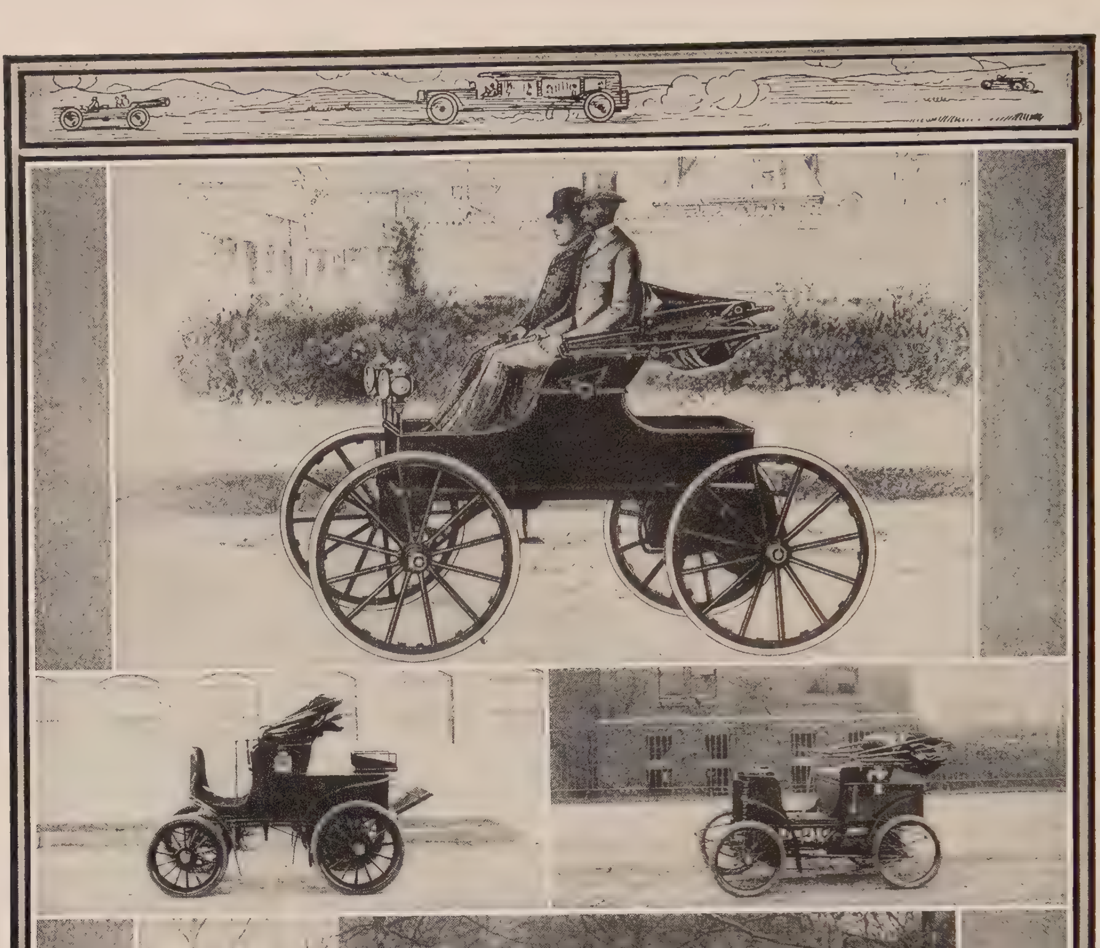
In "water-cooled" engines, the cylinders are surrounded with a hollow shell or jacket through which water is continuously pumped. The hot water passes from the jacket into a radiator, where it is cooled by air sucked through the radiator by a rapidly revolving fan.

Some types of engine, especially those used on motorcycles and airplanes, are cooled by exposing the cylinders to swiftly moving air. These, of course, are known as "air-cooled."

WHAT DOES THE CARBURETOR DO?

In order that the explosive mixture shall arrive in the cylinder in perfect form, the gasoline must be vaporized; it must be mixed with air and the proportions of air and fuel must be properly adjusted at all engine speeds. All this is done by the carburetor.

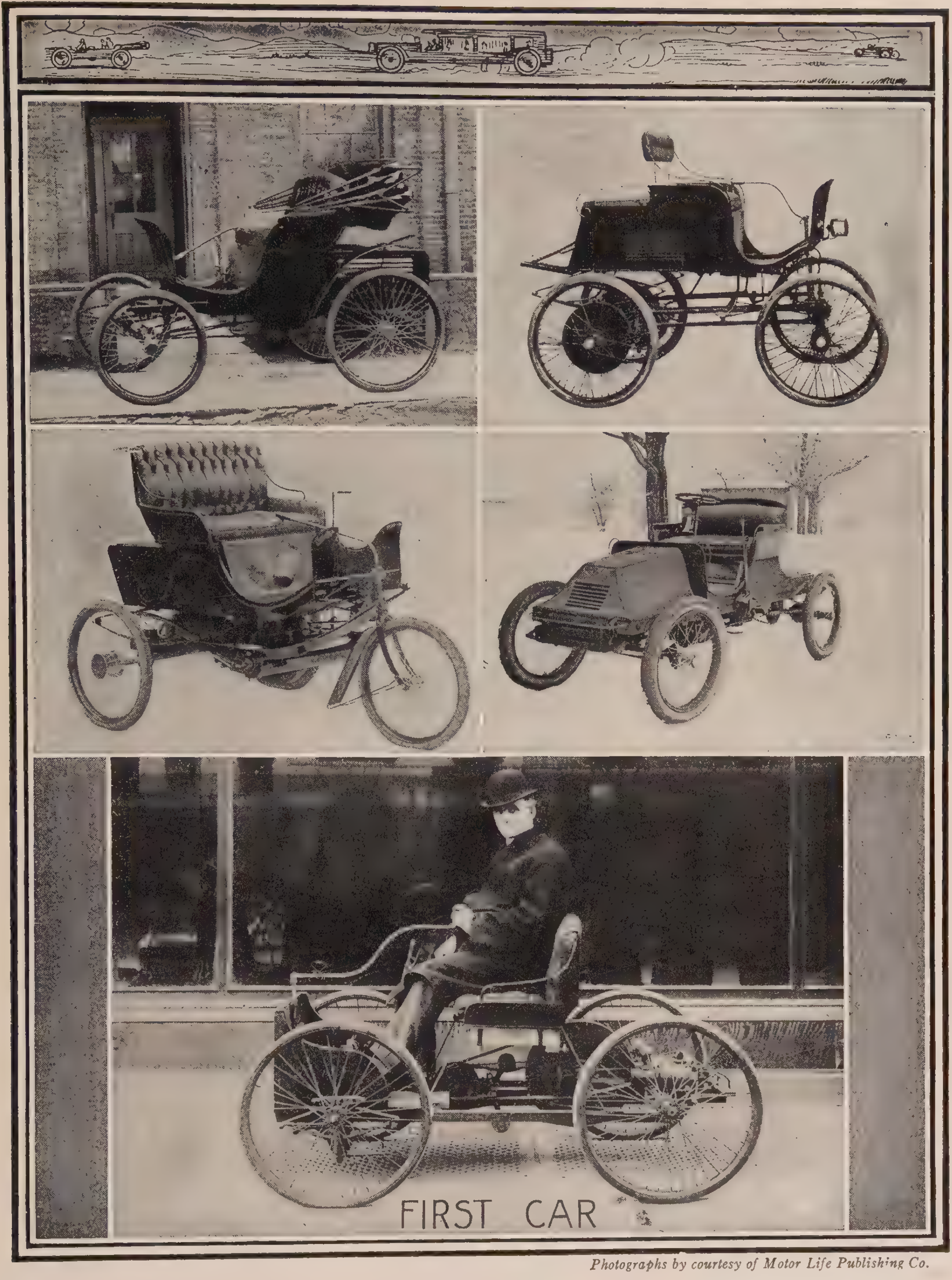
Gasoline flows from a storage tank into the float chamber, where it is automatically kept at the proper level by the float valve, which shuts the supply off entirely when the engine is stopped. Air is drawn in by the suction of the engine, and passing around the spray nozzle, picks up the proper amount of gasoline in the form of a spray. This is the explosive mixture which passes into the engine cylinder. The



Photographs by courtesy of Motor Life Publishing Co.

SOME EARLY CARS

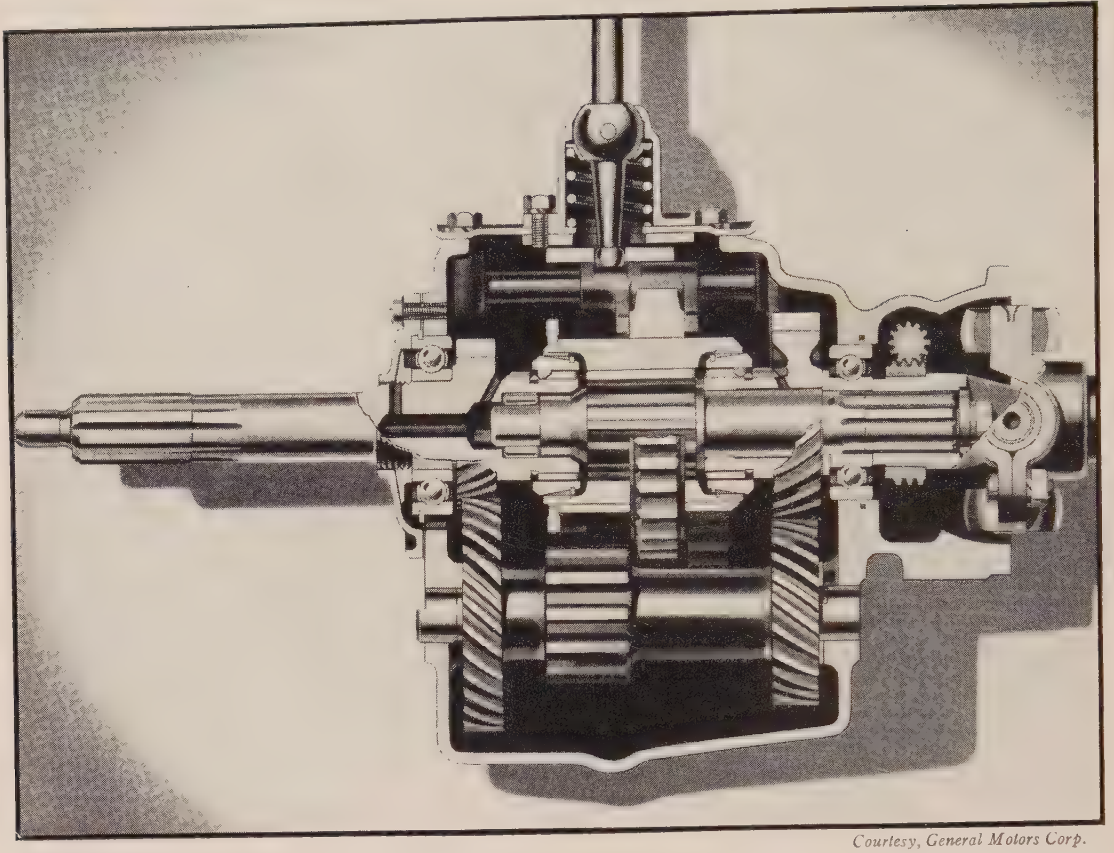
Top: Wood's Electric, 1896. Center: Columbia Electric, 1896–97, and Columbia Gasoline, 1896–97. Bottom: Duryea, 1898 (three cylinders).



Photographs by courtesy of Motor Life Publishing Co.

SOME EARLY CARS

Top: Winton, 1898, and Waverly Electric, 1898. Center: Knox three-wheeler, 1899, and Stearns, 1899–1900. Bottom: First Ford, 1903.



Courtesy, General Motors Corp.

A SLIDING GEAR TRANSMISSION

quantity of gasoline may be adjusted to the proper amount by using the needle valve. In most carburetors an auxiliary air valve is provided which opens at the higher engine speeds, providing more air and keeping the proportions of the mixture correct.

HOW THE CHARGE IS IGNITED

The explosive charge, having been admitted to the cylinder and compressed, is ignited by an electric spark. Naturally, there must be a source of electricity. Every automobile carries a storage battery, which, as its name indicates, is a reservoir for the storage of electric current. The battery is fed by a generator, or small dynamo, operated by the engine. From the battery the electricity passes through an induction coil, which so increases the pressure of the current that it will jump in the form of a spark across a small air gap. A spark plug in each cylinder provides the gap across which the spark leaps to perform its work.

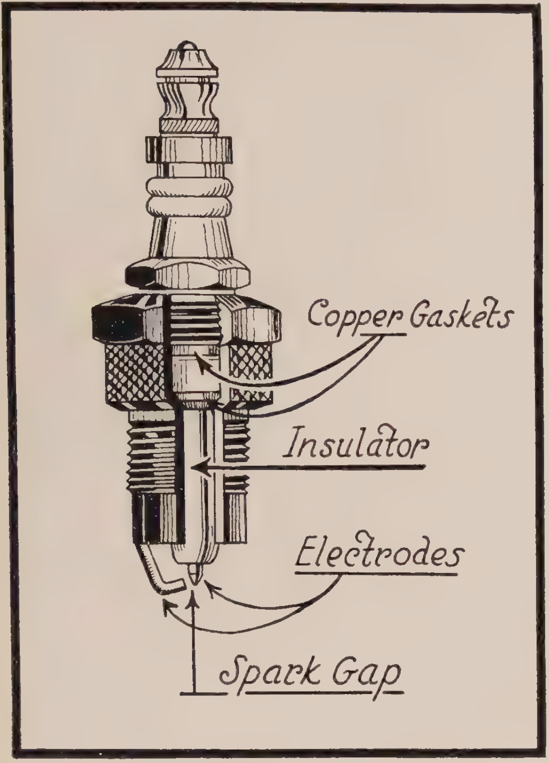
In engines of more than one cylinder, some means must be furnished to send a spark to each cylinder at the proper moment. This is cared for by the distributor, which is a sort of revolving electric switch sending current to each spark plug in turn.

The storage battery also supplies current for the lights, horn, and starting motor of the automobile.

WHAT IS A CLUTCH?

It is, of course, necessary to be able to stop the motion of an automobile while keeping the motor running. To accomplish this, the clutch is used. This is a means of disconnecting the engine from the gears and shaft which carry the driving power to the wheels, and is controlled by a foot pedal.

In its most common form, the clutch consists of two large discs, one of which is attached to the engine's flywheel and the other to the driving gears. Powerful springs press these plates together, and the resulting friction between them causes the gears and drive shaft to turn with the engine. When the pedal is pushed down, it compresses the springs, allowing the plates to separate and the engine to run free.



A SPARK PLUG

CHANGING SPEEDS WITH GEARS

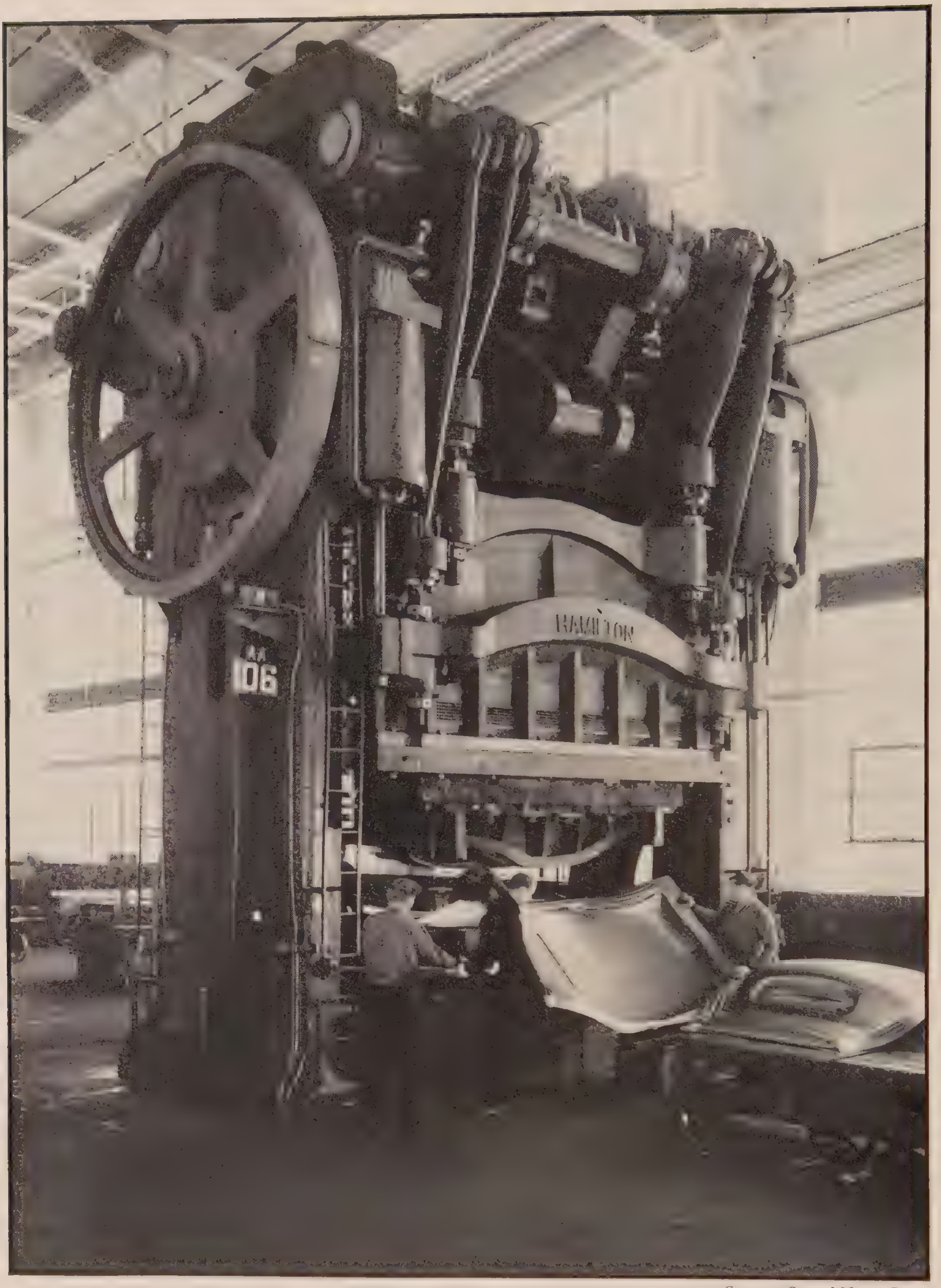
The more slowly a gasoline motor runs, the less power it has. The hardest work the engine has to do is to get the car started, and this is asking it to pull its heaviest load when it has the least power. To move the car slowly while the motor is running rapidly is the work of the transmission. If a small gear is made to drive a larger gear, it will revolve several times while the larger gear is turning once. When the small gear is attached to the engine and the large gear to the driving mechanism, the engine can run rapidly and develop full power while the car is moving slowly. This is the principle made use of in the "sliding gear transmission," shown in the accompanying diagram. Sets of gears are so arranged that they can be slid into different combinations for varying car speeds and for backing up. At high speeds, the motor is connected direct to the driving shaft.

THE DIFFERENTIAL

When a vehicle turns a corner, it is plain to see that the outside wheel must travel faster than the inside wheel. On a wagon or carriage the rear axle does not turn, and the wheels revolve loosely on the ends of the axle. Each may travel at its own speed without disturbing the other. In most automobiles, the axle must turn, as it is through this that the power is brought from motor to wheels. The rear axle is therefore divided in the middle, and a wheel fastened to each outer end so that axle and wheels will turn together. The two parts of the axle are connected by a set of gears called a "differential," so made that it allows the two wheels to turn at different speeds, at the same time delivering the proper amount of power to each wheel.

THE MOTOR TRUCK AND THE BUS

When automobiles are used for industrial purposes such as carrying merchandise or freight, they are termed commercial cars or trucks. Light trucks for fast deliveries often differ only from pleasure cars in the type of body. Trucks for hauling heavy loads are built with great weight and strength. Special gearing is used so that low speeds and tremendous pulling power are obtained. Many modern trucks are specially made for fast long-distance travel, and carry their huge burdens over the highways at railroad speed. Many special types of body have been developed, such as those with derricks for hoisting heavy objects, and others which may be raised for the delivery of coal and the dumping of sand or gravel. From a commercial point of view we



Courtesy, General Motors Corp.

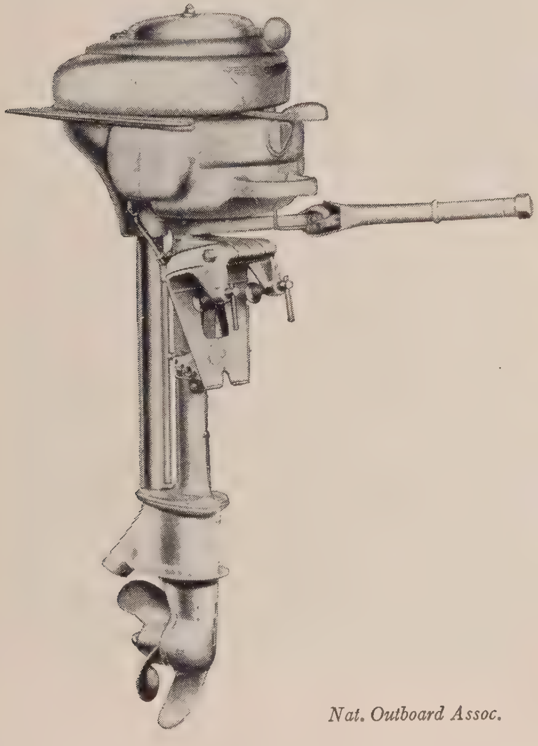
GIANT PRESS FOR FORMING STEEL BODY TOPS

could do without the telephone almost as easily as without the motor truck.

Motor buses now play an important part in the transportation of large numbers of passengers. They are not confined to tracks, as are trains and street cars, and consequently are especially useful in furnishing regular service in districts where steam and electric railways cannot be profitably operated. They are replacing street cars in many of our cities, and huge "coaches" operate regularly on long-distance schedules between the larger centers.

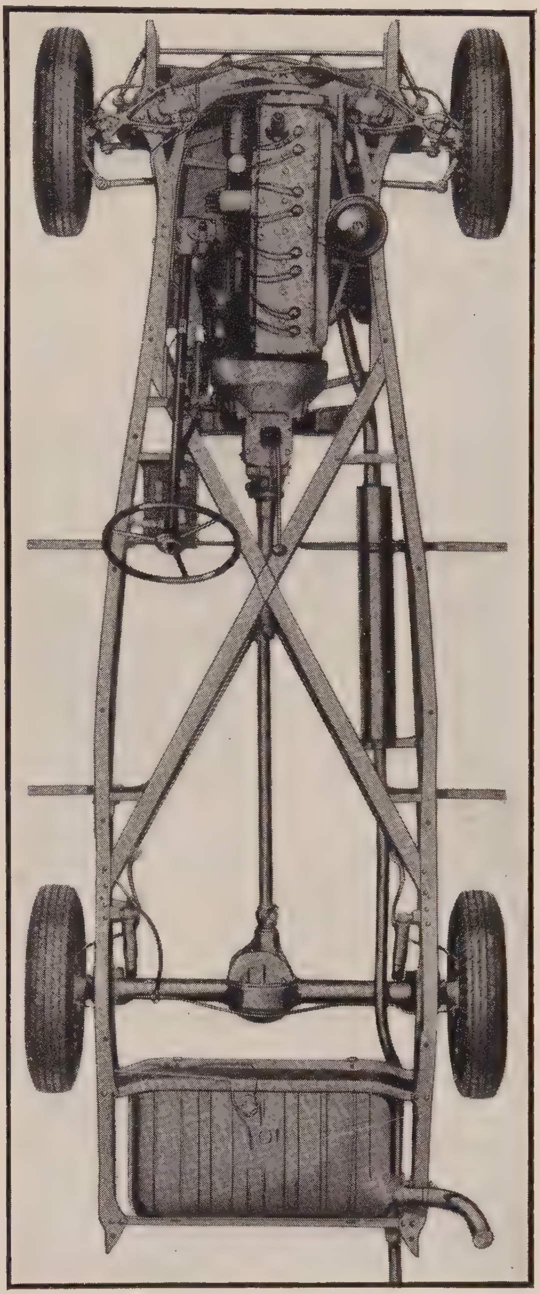
THE MOTOR BOAT

While many small boats still use an engine of the two-cycle type, most of the larger craft are propelled by a motor so like that of the automobile that we do not need to give a further description. The boat does not need the complicated transmission so necessary to the motor car, and rarely provides gearing for more than one speed forward and one backward. Speed is changed by regulating the supply of gas.



Nat. Outboard Assoc.

AN OUTBOARD MOTOR



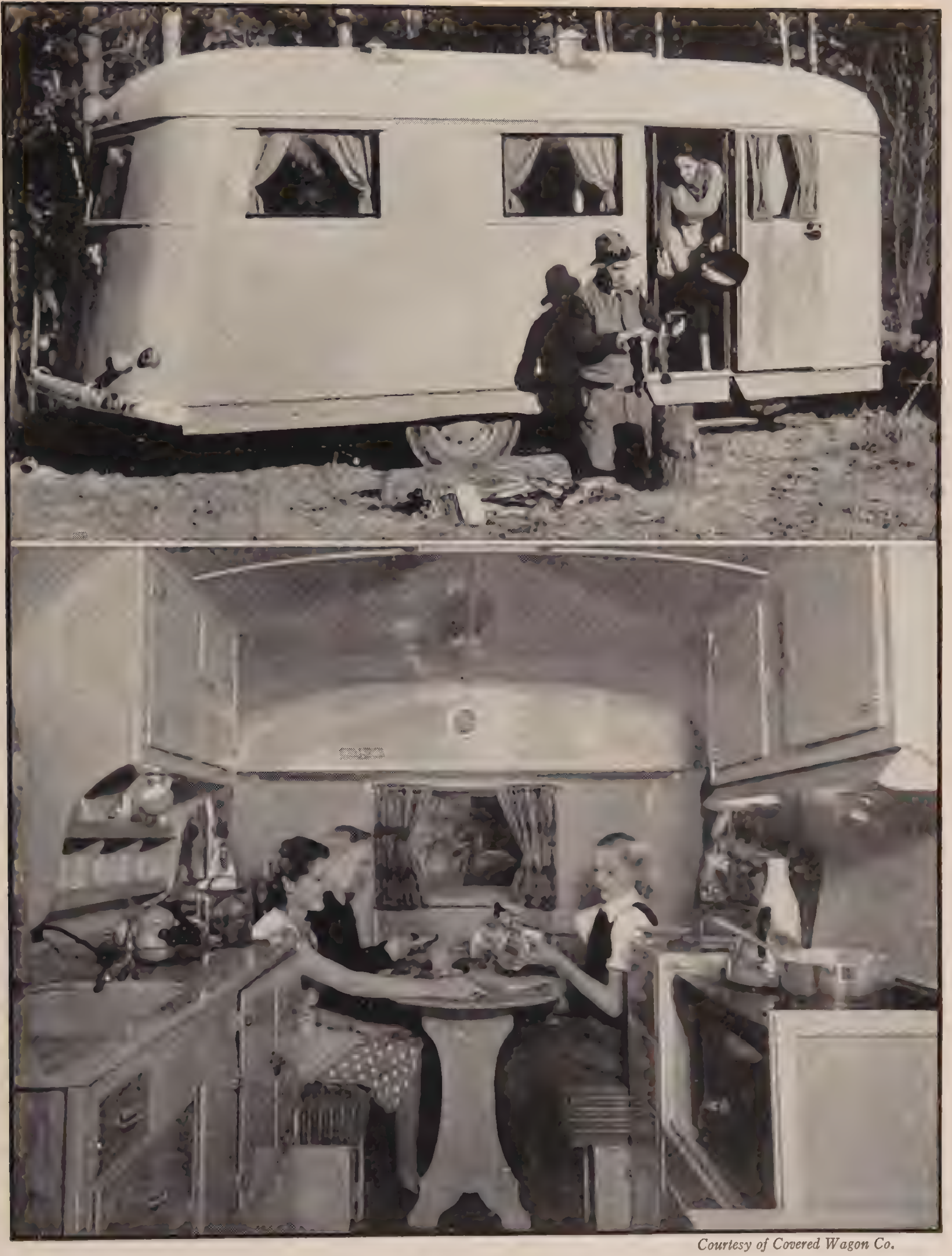
THE CHASSIS OF A MODERN AUTOMOBILE

By the chassis of an automobile is meant everything below the body of the car. This divides itself naturally into two parts: the power plant, consisting of the engine, muffler, cooling system, gasoline supply, and ignition system; and the running gear, which includes the transmission, driving shaft, differential, axles, wheels, frame, springs, steering gear, and brakes.

Courtesy of Fruehauf Trailer Co.

FREIGHT CARS OF THE HIGHWAYS

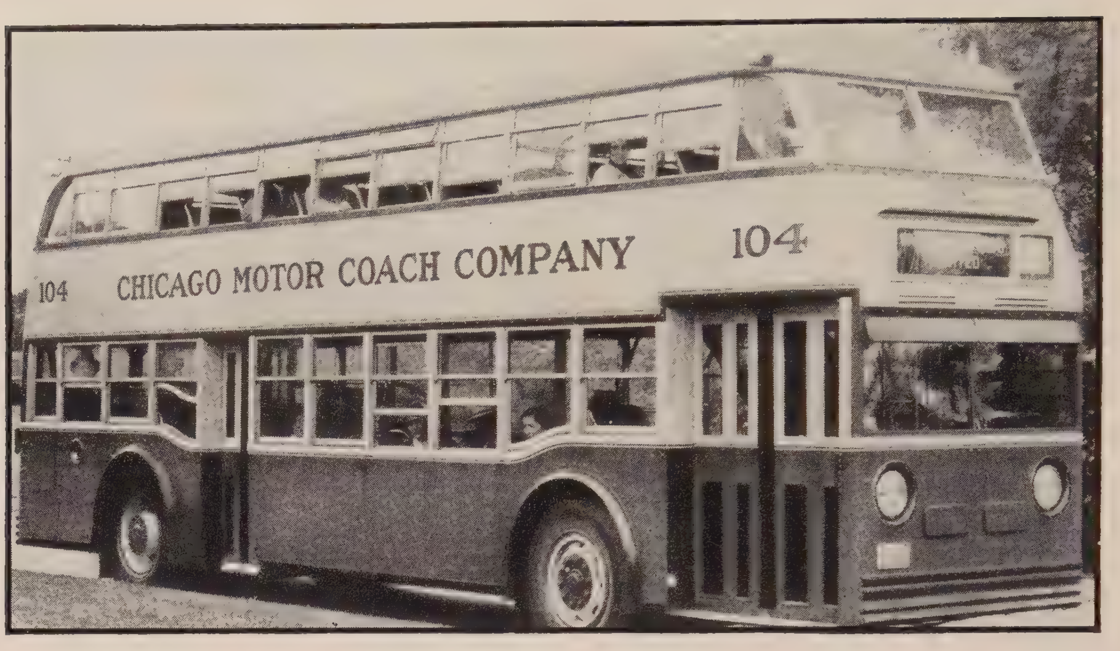
Huge motor trucks like these, with semi-trailer bodies, move a large part of the nation's freight.



Courtesy of Covered Wagon Co.

A HOME ON WHEELS

Exterior and interior views of an auto trailer. These comfortable homes on wheels have complete cooking equipment, running water, even shower baths. The table folds away and the seats come together to form a bed exactly as in a Pullman car.

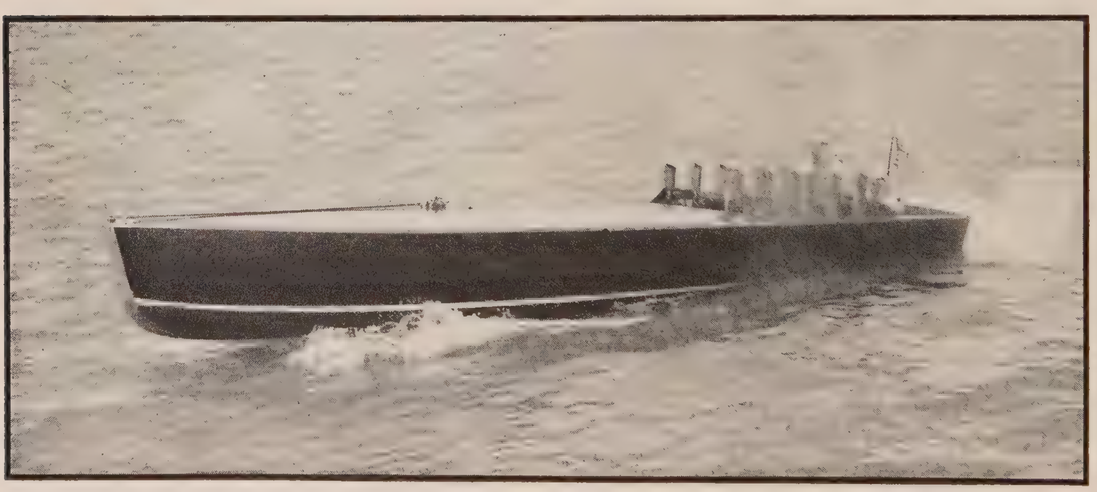


A DOUBLE DECKED MOTOR BUS WITH ENGINE AT THE REAR

Speed-boat racing has become an extremely popular sport, and some of the faster racing craft have their hulls so crammed full of engine that barely enough room is left for the driver.

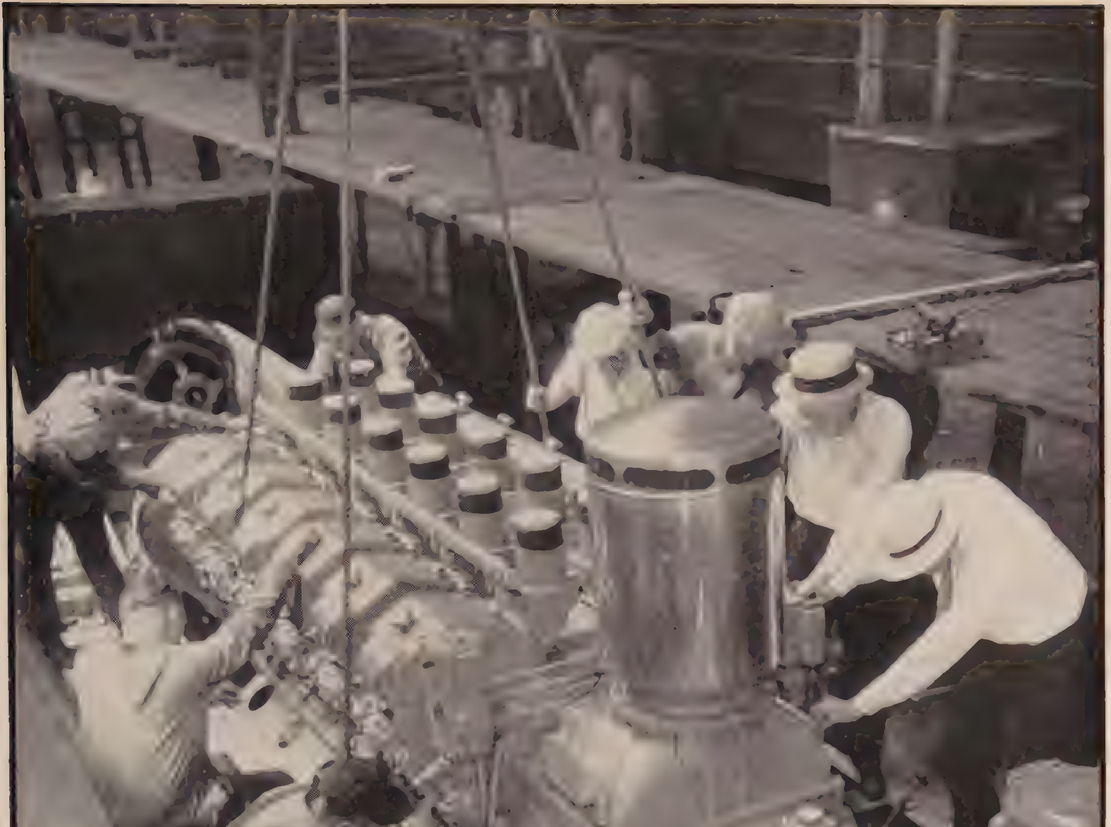
The great motors, sometimes with as many as twenty-four cylinders, drive these boats at speeds as high as ninety miles an hour.

An interesting development has been that of the outboard motor, a light, easily carried engine that may be clamped to the stern of a skiff or other boat. Each motor is a complete unit with its own gasoline tank, ignition system, and propellor. Such motors often weigh less than thirty pounds and can be used to propel a canoe at thrilling speed. Others develop thirty horse power or more and are used on boats large enough for cruising. Outboard



Keystone

A RECORD-BREAKING MOTOR BOAT



Courtesy, Union Pacific R R.

INSTALLING THE 900-HORSE POWER DIESEL ENGINE OF A STREAMLINED TRAIN motors are usually of the two-cycle type, and have from one to four cylinders.

Driven by these light yet powerful motors, small specially designed racing boats have reached speeds of over sixty miles an hour. More is told about the fascinating sport of outboard motor-boat racing in Volume VI.

THE DIESEL ENGINE

In great ships and in power plants on land, and more recently in streamlined railway trains, there is increasing use of a special kind of internal-combustion motor known as the Diesel engine.

It is very much like the gasoline engine in its cylinders, pistons and valves, but differs in the kind of fuel used and in its method of igniting the charge. There is no electrical ignition system used. Instead, the charge is fired by heat generated by the compression of the air in the cylinder. This sounds impossible. It seems more reasonable when we know that squeezing air to a pressure of five hundred to six hundred pounds per square inch increases its temperature to about 1000 degrees Fahrenheit. This heat is sufficient to ignite the fuel charge without the use of an electric spark.

The usual fuel for the Diesel engine is fuel oil refined from petroleum, although other fuels (even coal-dust!) have been tried experimentally. This oil is forced into the cylinder in the form of a spray.

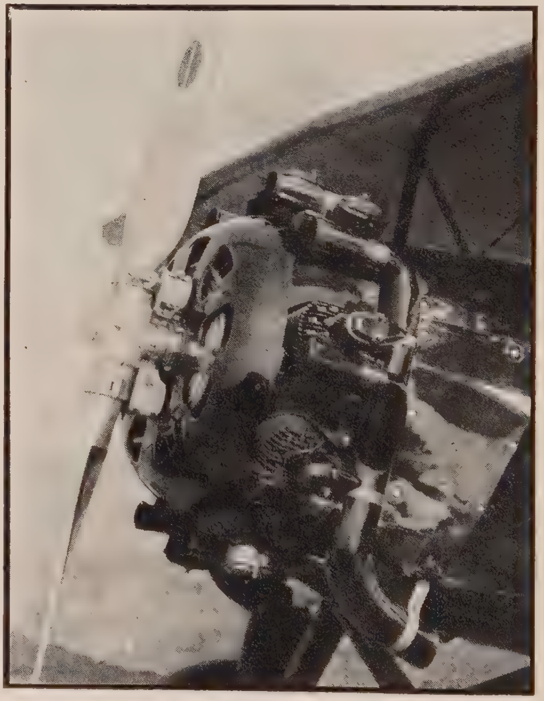
Because of the low cost and low consumption of fuel, the Diesel is the most economical of the internal-combustion engines. It has been built in units of 15,000 horse power for use on land, while it is not uncommon to find engines of from 6,000 to 10,000 horse power each in the engine room installations of the huge ocean-going motor ships.

Most of the more recent Diesel engines are built on the two cycle principle and the weight per horse power has been brought as low as 17 pounds. This weight, which is light when compared to the 250 pounds per horse power of many early Diesel engines, has opened up a wide variety of uses for the Diesel. The most popularly known use is in streamlined railway trains. (See Volume Four, pages 346 and 349.) Diesel engines also are used in some of the larger tractors and motor trucks.

PERFECTING THE GASOLINE ENGINE

The men who make internal-combustion engines are ever working toward simplicity, greater economy of fuel, and strength combined with light weight. In the automobile, airplane, and motor boat of to-day, the gasoline engine has reached a high degree of perfection. Only through its development was aërial navigation made possible. In the section on "Conquering the Air" it will be seen how greatly aviation depends on the light weight and reliability of the gasoline motor.

It is interesting to reflect that the development of the portable internal-combustion engine and its growth from an experimental mechanism to a highly dependable power plant have taken place in the short space of about fifty years. To Gottlieb Daimler, a German engineer, is credited the invention of the light high-speed gasoline engine. To him and his associates we also owe the forerunner of the modern carburetor. Daimler and Carl Benz, another German, both produced motor cars about the same time (1885), and which one of them was first is often disputed.



A DIESEL AIRPLANE ENGINE

SAFETY ON THE HIGHWAY[1]

IN every game, certain acts are recognized as fair and other acts as foul. Spectators admire and applaud fair play. They are irritated by fouls, and often protest and boo.

Try excusing the kind of player who habitually fouls at any game, by saying that he does not mean to foul, that he may be ignorant of the rule involved! "What business has he in the game if he doesn't know the rules?" irritated spectators will growl.

A good sportsman knows the rules. And today there are important rules of the game both for driving an automobile and for walking on the public streets and highways. Violation of these rules is not only poor sportsmanship but almost certain to be punished sooner or later by injury to yourself or to others.

SPORTSMANLIKE DRIVING

The obligations of good sportsmanship rest even more heavily upon the driver of an automobile than upon the pedestrian. An automobile driver is responsible not merely for his own safety but for that of his passengers, for the occupants of other vehicles, for playing children and other pedestrians, for bicycle riders, animals, and for properties bordering on the highway.

The driver must share the highway with any number of others who may be using it. He is not driving in a desert or on a private race track; he is using a public highway.

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When any space has to be shared, it is wise to have an understanding about what is a fair division. Each driver has first right to certain portions of the roadway at certain times. But he has no right to other portions of the roadway—portions which, at certain times and under certain circumstances, belong exclusively to other drivers or to pedestrians.

Drivers, for example, have first right to the right-hand side of the road but may borrow the use of the left, for passing, at times when that side is not wanted by the drivers who have prior right to use it, and when the use of it will in no way endanger others. Or a driver has first right at intersections having traffic lights, only at times when the signal so indicates. The pedestrian has first right on crosswalks only when the signal indicates that it is his turn. The pedestrian always has the right-of-way over turning vehicles. Emergency vehicles, such as fire department equipment, police cars, and ambulances, have first right to use the streets and highways in emergencies.

PROTECTING THE PEDESTRIAN

It is the duty of the driver to safeguard the pedestrian, who is in the weaker position. He is neither as heavy nor as speedy as the car. Therefore, in any collision, he is almost certain to suffer injury.

The driver is obligated to keep his car so thoroughly in control that there will never be a time when he cannot stop quickly enough to avoid hitting even those who may carelessly step into the streets from unexpected places. Since control of the car is largely a question of proper speed, one of the surest ways of protecting the pedestrian is by using good judgment in the matter of speed.

KEEPING THE CAR IN GOOD CONDITION

A car on an unoccupied desert can be in as run-down a condition as possible, and no one but the driver himself will have reason to complain. But when we must share the public highway with drivers whose cars are in such condition that they cannot be kept in control, any one of us has just cause for complaint.

The first time we meet a car with only one headlight we begin to realize the importance of the two lights to tell us how much clear space we have in the roadway ahead. The car with one headlight keeps us guessing, sometimes up to a dangerous point, as to just which light is out and on which side of the "good" light is the bulk of the car.

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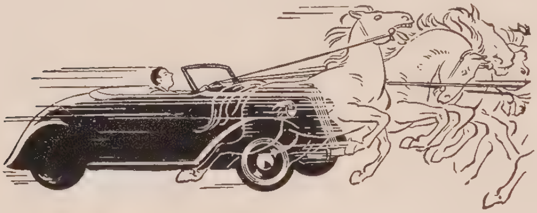
[1] Adapted from "Sportsmanlike Driving," a series of pamphlets published by the American Automobile Association.

The driver is responsible for the condition of the car and is neglecting a social obligation if tires are in such poor condition that they may, by blowing out, throw the car out of control; if brakes are so worn or poorly adjusted that the car's stopping distance is increased beyond safe limits; if the steering mechanism is defective; if the mirror and windshield wiper are so ineffective that he cannot see as well as he should. Such a car is a public menace.

Control is the keynote to skilful driving, and is at its best only when the car's safety equipment is properly maintained.

THE THRILL OF POWER

Most persons like strong, powerful things and forces — the mighty seas and the high mountains. Moreover, there is a recognized tendency to identify ourselves with such mighty things, and thereby get a thrill of reflected power. It is not surprising, then, that the power of the automobile is a source of thrill.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But power loses much of its thrill and romance when it is not under control. Man is reduced to a weak and foolish-looking creature when the power he is supposed to be directing runs away with him. It is not simply power that man really wants: it is power under control. All drivers have the sense of power. Only good drivers have the sense of power under control.

EXPERT DRIVING

Only a "good sport" can become an expert driver. Expertness never comes to the slipshod, discourteous driver. The expert is not a bungler. Expertness comes through conscientious effort.

The fine no-accident records that have been established by some drivers are nothing less than an inspiration. One is known to have driven 1,707,800 miles in 15 years without an accident! Others have covered 500,000 miles in six years, 231,000 miles in five years, and 256,000 miles in six years without accidents. Sportsmanlike, controlled driving greatly helped these veterans to achieve such enviable records.

PEDESTRIAN HABITS

In the days of our grandparents, who would have thought that the time would come when people would need to learn to walk safely on streets and roads? But the time is here.

In one recent year, over 16,000 pedestrians were killed and almost 280,000 were injured. Some of these were responsible for their own destruction. Many had not properly learned where to walk, when to walk, or how to walk. Sound pedestrian habits would have saved a very large proportion from death or injury.

To be up-to-date and fit into our motor age, we need a few very definite habits that were unheard of a generation or two ago.

GENERAL STREET HABITS

Certain desirable practices apply no matter where one is walking. In this group are the habits of:

1. Not standing in the street.
2. Playing away from traffic.
3. Crossing busy streets only at intersections.
4. Not stepping into the street from behind or in front of parked cars.
5. Stepping out of a parked car on the side away from traffic.
6. Walking — not running — across streets.
7. Never "weaving" through traffic.
8. Watching for cars that are backing.
9. Compensating for eye or ear defects with special care.
10. Taking special care in traffic at certain exceptional times —

When in a hurry.
When carrying an umbrella or bundles.
When the streets are slippery.
When crowds are dispersing.

HABITS AT INTERSECTIONS

There will be a sharp decrease in pedestrian accidents when all act at intersections according to a few simple rules. These rules are as follows:

1. At protected corners, start to cross only with the GO signal.
2. If you see that the signal is about to change against you, WAIT.
3. Be sure the way is clear. Look to the left and then to the right before starting to cross.
4. Watch for cars about to make turns.
5. If confused while crossing, avoid sudden moves.
6. Walk straight across, not diagonally, at intersections.
7. Keep to the right on crosswalks.

HABITS RELATING TO STREET CARS AND BUSES

As pedestrians we also need the following habits:

1. Waiting on the sidewalk until the street car or bus arrives (at places where there are no adequate safety zones).
2. Facing oncoming traffic (at places where it is necessary to wait in safety zones).
3. Never crossing immediately in front of vehicles from which we have stepped.
4. Waiting on the safety zone until we see that our path to the curb is clear.

WALKING HABITS ON RURAL HIGHWAYS

Certain habits are useful when we walk in the country. They are:

1. Using highway paths and sidewalks wherever they are provided.
2. Walking on the LEFT of the highway.
3. Stepping off the road when two cars are about to pass each other near-by.

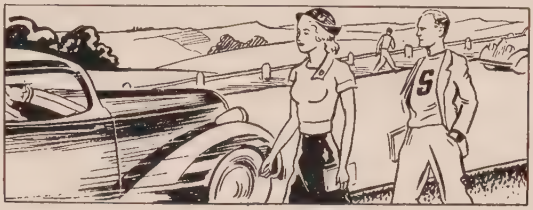
Where special pedestrian paths and sidewalks have been provided, the pedestrian has no right-of-way on the roadway.

When the pedestrian walks on the left side of the road he faces approaching cars. He sees them in time to adjust himself to their actions and does not run the constant risk of being struck from behind. Some rural roads are so narrow that when cars meet each other at the spot where a pedestrian is walking, the smallest slip on the part of either driver may easily result in the cars side-swiping, and hitting the pedestrian — or the nearer car may brush him.

Certain habits are especially desirable when we walk on the roadway at night. These are:

1. Walking on the LEFT.
2. Wearing something white.

The practice of walking on the left is even more important at night than in the daytime. The pedestrian can see the headlights of an approaching car long before the driver can see him. If the weather is bad, the driver may be so handicapped by poor visibility that practically the whole responsibility for safety falls on the pedestrian himself. At such times it is most important to walk on the left, facing oncoming traffic.



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Experiments show that the distance at which a driver can see a person on foot at night is greatly increased when the pedestrian wears something white. The motion of a white handkerchief carried in the hand helps a driver "spot" a person walking along the road. Any white clothing which the driver can see is helpful. The pedestrian who is dressed in dark clothing should be sure to carry a light or something white.

In the complicated traffic of our motor age the person on foot cannot afford to be equipped with merely accidental walking skills. He needs habits "custom-built" to fit his special needs. By thoughtful repetition of sound practices these habits can be formed.

FAMOUS FIRST FLIGHTS OF THE TWENTIETH CENTURY

FROM HEMISPHERE TO HEMISPHERE

The United States Navy Seaplane NC–4, under Lieutenant Commander Albert Cushing Read, was first to fly from the Western to the Eastern Hemisphere, accomplishing this feat in May, 1919.

First flight in a power-driven airplane: Orville and Wilbur Wright, at Kitty Hawk, N. C., December 17, 1903.

First flight across the English Channel: Louis Blériot, July, 1909.

First transcontinental flight: Calbraith P. Rodgers, New York to California, September-November, 1911.

First transatlantic flight: Lieutenant-Commander Albert C. Read, commanding U. S. Navy airplane NC-4, May 16-17, 1919.

First non-stop transatlantic flight: Captain John Alcock and Lieutenant A. W. Brown, Newfoundland to Ireland, June 14, 1919.

First transatlantic flight by airship : Zeppelin R-34, Scotland to the United States, July 2-6, 1919. Its return trip completed the first round-trip transatlantic voyage by air.

First-round-the-world flight: United States Army, three planes, April 6-September 28, 1924.

First flight over the North Pole: Lieutenant-Commander R. E. Byrd and Floyd Bennett, May 9, 1926.

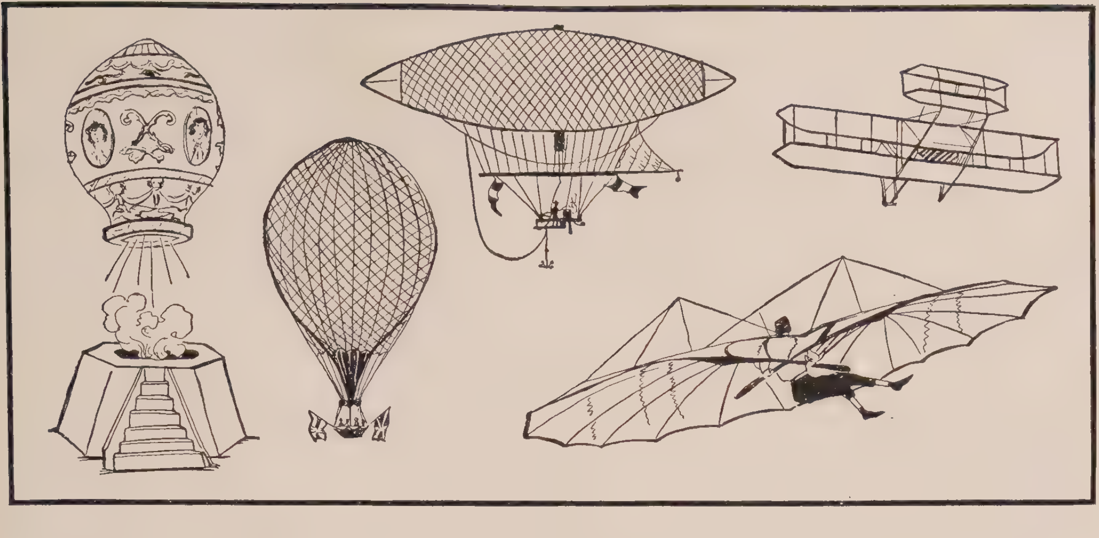
First New York to Paris non-stop flight: Colonel C. A. Lindbergh, May 20-21, 1927.

First United States to Hawaii non-stop flight: Lieutenant A. F. Hegenberger and Lieutenant L. J. Maitland, June 28-29, 1927.

First flight over the South Pole: Rear Admiral Richard E. Byrd and Bernt Balchen, November 28-29, 1929.

First transpacific commercial flight: Pan American Airways, October, 1936.

First transatlantic commercial flight: Pan American Airways, June, 1939.



EARLY AIRCRAFT

Montgolfier's Balloon; The Great Nassau Balloon; The First Dirigible; Lilienthal's Glider; The Wright Airplane.

CONQUERING THE AIR

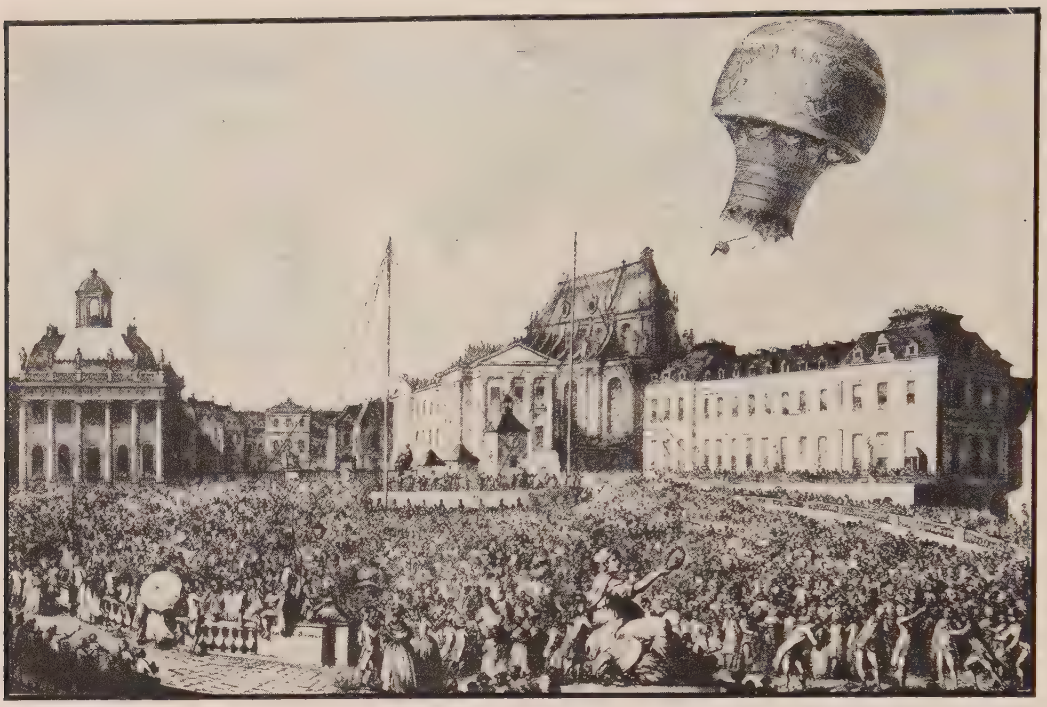
THE STORY OF THE DEVELOPMENT OF AIRCRAFT

THE gasoline engine, so light in weight and using so perfect a fuel, has made possible the navigation of the air. Through it man's dream of the centuries is realized, for man has planned and hoped and dared and died in attempts to navigate the air for no one knows how long. In the old Greek myth Dædalus and his son Icarus are fabled to have flown by means of wings fastened on with wax. But the increasing heat of the sun melted the wax, and one of these mythical early airmen fell to the ground and was killed. Through one mishap or another scores of modern airmen have met a similar fate; yet in spite of this, man has through the gasoline motor, learned to fly thousands of miles, moving at a speed rarely equaled in any other type of vehicle, remaining in the air for long periods and alighting safely.

EARLY IDEAS ON FLIGHT

While the legend of Dædalus and Icarus is shrouded in the mists of antiquity, records as far back as three hundred years before Christ give evidence of attempts to solve the problems of flight. In that far gone day, one Archytus of Tarentum is said to have fashioned a wooden imitation of a dove, which was made to fly by mechanical means. As time went on, the minds of dreamers were filled with wild ideas and schemes. It was suggested that because the sun drew up the dew, a man could float away serenely by attaching dew-filled eggshells to his belt. The clergyman, John Wilkins, Lord Bishop of Lancaster, suggested the exploration of the sky by help of the spirits of angels. He further wrote of the use of fowls; wings fastened to the body; and a flying chariot. "In the course of years," said this man of vision, "people will call for their wings as frequently as they call for their boots."

Francesco Lana, a seventeenth century monk, devised a boat which was to be carried upward by four large balls of very thin copper. All that is necessary, thought he, is to suck out the air and these balls will float through the heavens like a tin can in a pool of water. Unfortunately he did not realize that the atmosphere, exerting a pressure of nearly fifteen pounds to the square inch, would instantly collapse these globes of paper-thin metal. Nevertheless, his scheme was actually tried by one Marey Monge,



AN EARLY BALLOON ASCENSION

The Montgolfier balloon in flight at Versailles.

who spent twenty-five thousand francs and was rewarded with a few pounds of junk copper, fantastically twisted by the air.

MONTGOLFIER'S BALLOON

The balloon was the first vehicle which in modern times carried men into the air, and its use was hailed with extraordinary enthusiasm. Many people believed that the whole problem of air navigation was solved. We know to-day, of course, that it was not, and that only a first step had been taken. It was more than a century and a half ago that a balloon made its first triumphant flight, but until the gasoline engine came into use the balloon remained the sport of the element in which it floated, blown hither and thither by the wind like a skiff without oars or rudder. Yet even to float securely in the air was a great triumph for the time, and the way to do this was shown by the Montgolfier brothers in France.

Someone had already proposed capturing a cloud in a bag, without, of course, saying anything about how it could be caught. Joseph Montgolfier, a paper maker, was thinking about this one day as he opened the door to his living room. In front of the fireplace his wife had hung a silk petticoat to dry. When Joseph opened the door, a draft brought the smoke swirling out into the room, where it filled the petticoat and carried it triumphantly to the ceiling. "Well," mused Joseph, "If I cannot capture a cloud in a bag, I can capture some smoke, and perhaps. . . ."

With the assistance of his younger brother, Stephen, the experiment was tried in November, 1782. A square bag of silk, three or four feet on each side, was placed over a fire of burning wool. It swelled, bulged, and rose to the ceiling of the room. Later they repeated their experiment outdoors, with a larger balloon. Tearing loose from its restraining ropes, it soared six hundred feet into the air.

In June, 1783, the Montgolfiers went to Paris and gave a demonstration for the benefit of the French Academy of Sciences. This time the balloon was an affair of some importance, seventy-two feet high, with sides decorated with brilliantly painted designs. It went up six thousand feet in ten minutes, floated along the gentle wind for more than a mile, and descended unharmed. Among the astonished observers was Benjamin Franklin, who not only belonged to the Academy, but was serving at the time as our ambassador to France.

THE FIRST AËRIAL PASSENGERS

This balloon had neither car nor occupants, but it was clear that one could be built which would be capable of lifting a man. But was it safe? Man could not breathe under water; perhaps there were similar conditions high up in the air. The natural thing was to try it out with dumb animals first. So, on September 19, 1783, with the King of France as a spectator, Joseph made more smoke with a fire of wool, and up went the first aërial passengers, a sheep, a rooster, and a duck. Eight minutes later the car returned to the earth in safety.

The next step was for a man to try it. It was at first suggested that a condemned criminal be chosen, and that his life be spared if he succeeded in coming down alive. Jean François Pilatre de Rozier objected that to be the first man to navigate the air was too great an honor for a criminal. Hence this brave young Frenchman himself made the first trip. On October 15, 1783, he stepped gallantly into the car and was let up to a height of eighty-four feet by means of a rope. He came down again nearly five minutes later and declared that he had enjoyed himself thoroughly.

THE FIRST PASSENGERS

PROFESSOR CHARLES' HYDROGEN BALLOON

Some five weeks later, de Rozier and the Marquis d'Arlandes wrote their wills and went up from the gardens of the Château de la Muette in the Bois de Boulogne for the first free flight in history. The wind was gusty, in spite of which they had a successful trip. They could look down on the city of Paris, and by throwing fuel into the grate in the car, rose to a height of three thousand feet and descended in safety.

THE HYDROGEN BALLOON

The hot-air balloon was swiftly followed by ones filled with hydrogen. This gas, so easily made and so extremely light, had been discovered just a few years before, and was found to be of great lifting power and lasting. It offered

REPAIRING THE GAS BAG OF THE ANDRÉE BALLOON

many advantages over hot air, but even with it the balloon was but a plaything of the winds. Being able to go up into the air was satisfying enough for a little while, but that was only a small part of what the birds could do.

Fanlike oars of various styles were tried with no success whatever, and several men revived an idea of Bishop Wilkins by suggesting various means of towing a balloon with trained eagles. This brilliant idea was even proposed as a quick means of getting to California during the gold rush of 1849, when the fastest journey involved a three months' sailing voyage around Cape Horn.

In 1825 the French engineer, E. C. Genet, visioned a horse balloon. He imagined a cigar-shaped airship, one hundred and fifty-two feet long, beneath which two horses were to be suspended on a platform. With flying manes and arched tails, the animals were to maintain a spirited gallop on a treadmill, which in turn would operate a large paddle wheel. Unfortunately, such animals offered neither the small size nor the insignificant weight which would assure success. The gasoline engine had not yet been thought of.

In 1851 Giffard came gloriously near to success by using a one-cylinder, three horse-power steam engine to drive a three-bladed propeller.

EARLY VOYAGES

During the siege of Paris, which ended the Franco-Prussian war, M. Nadar organized the "Balloon Poste" by which letters could be gotten out of Paris. Unfortunately no mail could be brought back by the same means, because it was impossible to steer a balloon.

In spite of this serious limitation, Salomon August Andrée, a Swedish engineer, left Spitzbergen on July 11, 1897, in a balloon not very different from the first hydrogen balloon of Professor Charles. He expected to fly across the North Pole. A few days later, one of the carrier pigeons taken with the expedition was shot by a seaman on the whaler *Alken*. The following message was taken from the bird: "13th July, 12:30 P. M. Good journey eastward, 10 degrees south. All goes well on board. This message is the third sent by pigeon.

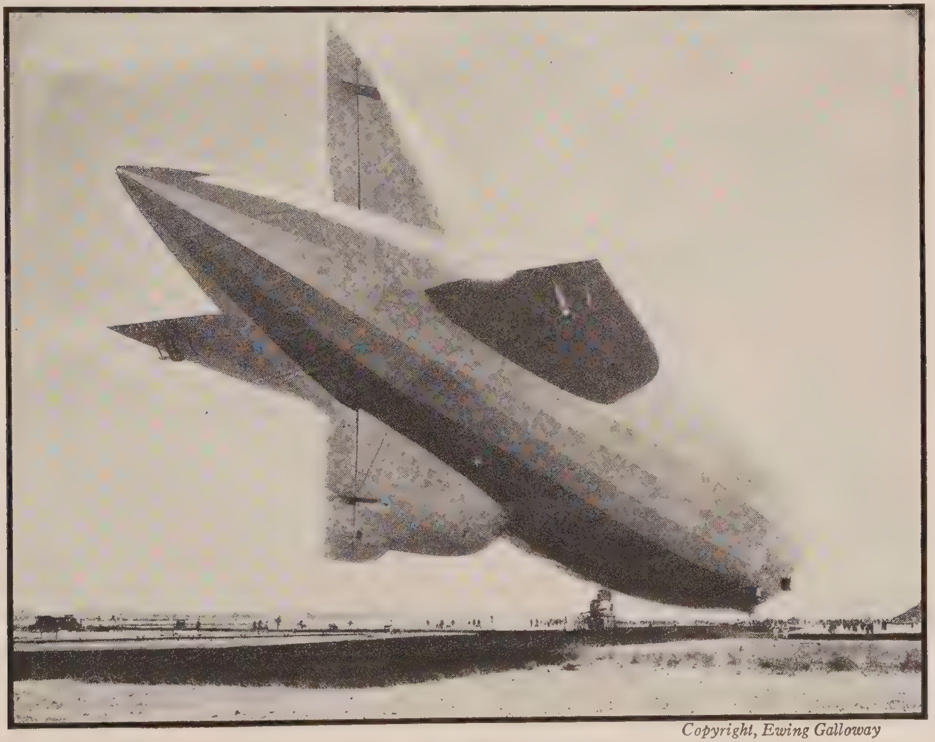
Andrée." After that came icy silence and cold mystery.

In 1901 it was rumored that the bodies of two white men and the basket of a balloon had been found in northern Canada. For almost thirty years this was thought to have been the remains of the Andrée expedition. In August, 1930, a Norwegian expedition discovered two bodies on White Island, almost due east from Spitzbergen. From one of them were taken the log of Andrée's balloon and his personal diary, which told an incredible story of the long trek across the ice and the weeks of heroic struggle that had remained a mystery for thirty-three years.

The first aërial craft to make a journey and return to its starting point was "La France." In 1884 Captains Renard and Krebs of the French army ascended from the military balloon ground at Chalais-Meudon, covered a distance of two and a half miles, and returned at a height of a thousand feet, alighting safely at the point of departure. From that time on the war departments of several European nations, especially France and Germany, vied with one another in producing monster airships whose great lifting power, great engine power, stability, and ease of control made them really wonders of the modern world. In 1898 Santos-Dumont, a brilliant young Brazilian, began building small dirigibles in Paris, in eight years constructing fourteen airships and rousing enthusiasm in regard to air navigation to the highest pitch.

THE AIRSHIP

Count Zeppelin of Germany was the most indefatigable airship builder. His enormous dirigibles, Zeppelin I, II, III, were the marvel of their time in size and achievements. Through his efforts, the enthusiasm of the German War Office, and the backing of the whole German people, Zeppelin's first was begun in 1898 on the lake not far from the town of Friedrichshafen. The envelope was prismatic, with 24



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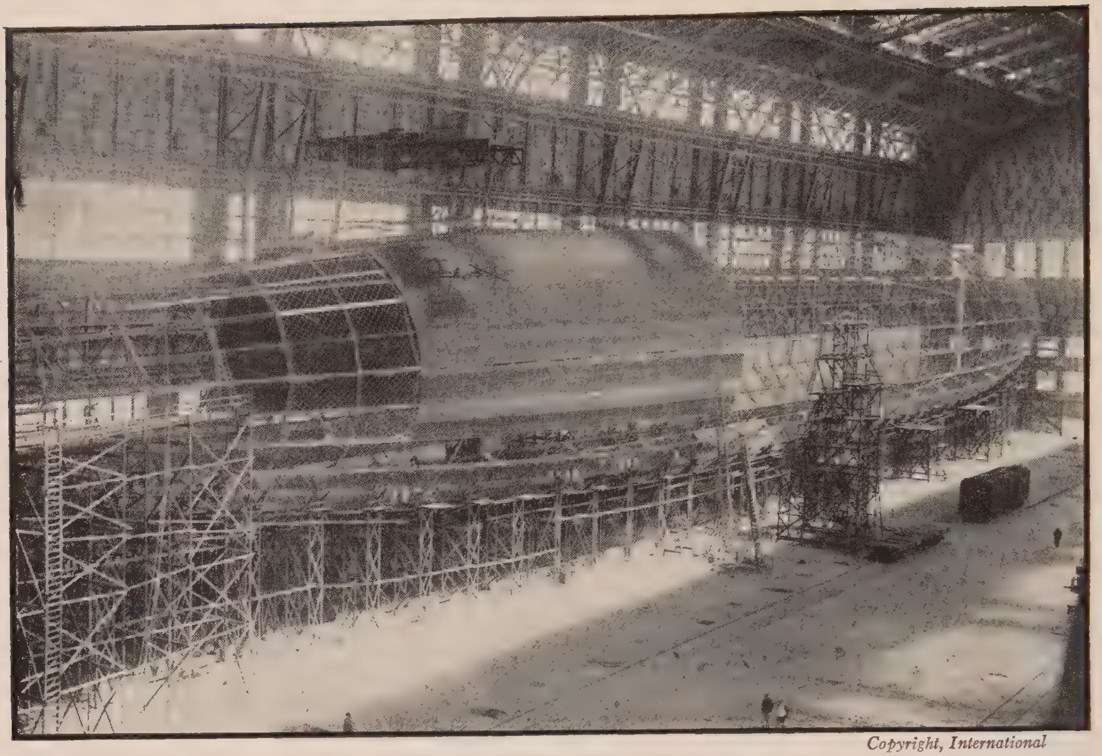
THE GRAF ZEPPELIN

An unusual view showing the huge elevators and rudders.



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A DIRIGIBLE UNDER CONSTRUCTION

surfaces, 420 feet from end to end, and 38 feet in diameter, coming to a gradual point at each extremity. The framework of the envelope was of aluminum latticework, covered with linen and silk material treated with pegamoid. In each of the seventeen compartments were linen gas bags, together capable of holding some 400,000 cubic feet of hydrogen, leaving an air space between them and the outer covering which would prevent any sudden alterations of temperature and consequent ascending or descending of the vessel. Two cars about twenty-two feet long were rigidly attached below the envelope, less than a quarter of its length from each end, and to give additional strength and rigidity a triangular keel of aluminum latticework was attached below these cars, and from this was suspended a movable weight worked by a winch, enabling the bow of the vessel to be directed up or down. In each car was a sixteen-horse-power motor, driving two four-bladed screw propellers fitted with reversible gears, so that the airship could be driven either ahead or astern. The main vertical rudder was fixed to the stern of the envelope, while for steering purposes and intercommunication the cars were fitted with electric signal bells.

During the World War of 1914-1918 Germany built a large number of Zeppelin airships which she used for sea scouting and for bombing raids over England. The huge gas bags were easy targets for the faster airplanes, however, and although England, France, Italy and the United States experimented with dirigibles after the war, the idea of using them for military purposes was abandoned long before the outbreak of the second World War.

Even the peaceful uses of the dirigible proved disappointing. Germany built two large passenger-carrying dirigibles, the Graf Zeppelin and the Hindenburg, and for a time used them in regular commercial flights from Germany to the United States and to South America. But the Hindenburg was destroyed by fire when about to land at Lakehurst, New Jersey, on May 6, 1937, and 36 of the 97 passengers lost their lives. This disaster marked the end of attempts to use dirigible balloons for commercial purposes.

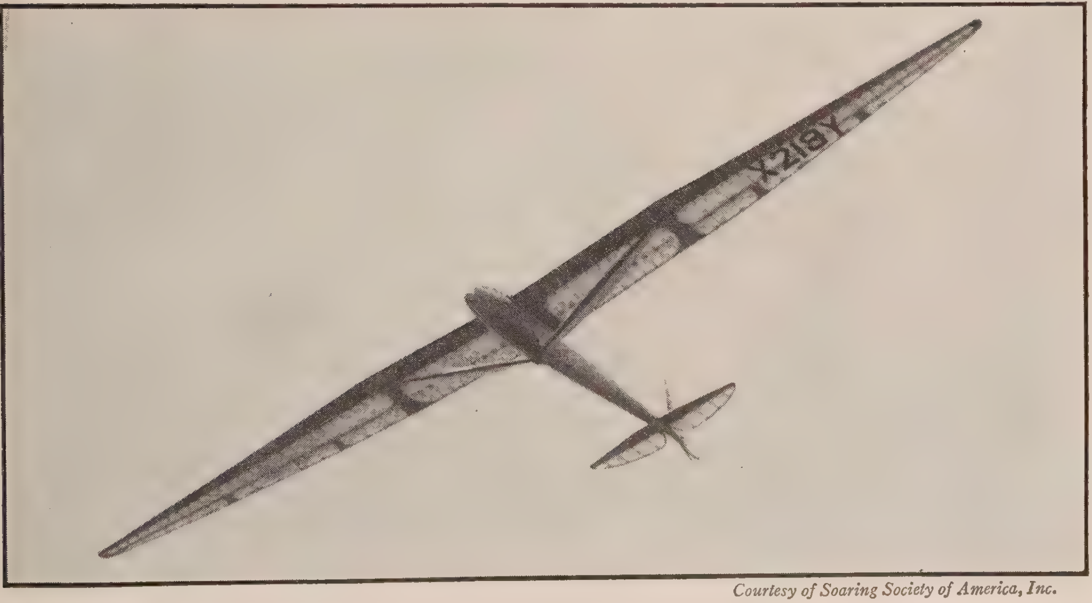
THE CAYLEY GLIDER

For nearly a hundred years before the Wright brothers flew, the idea of the airplane, that is, of flight by means of a heavier-than-air machine, had been gradually developing. Sir George Cayley made the first important contributions. He was a boy of ten when the exciting news of the Montgolfier discovery was made known. His imagination grasped at once the possibilities of flight, with the result that he devoted his entire eighty-four years to the problems of heavier- and lighter-than-air machines. No experimental device of his was more interesting than a glider which he constructed in 1808. It had a wing surface of three hundred square feet. From the hill behind his ancestral estate he launched it — much excited because "It was beautiful to see this noble white bird sailing majestically from the top of a hill to any given point of the plain below it, with perfect steadiness and safety, according to the set of its rudders, merely by its own weight descending at an angle of about eighteen degrees with the horizon." He found the upward lift of this "gliding machine" so strong that anyone running with it against a light breeze would be raised from the ground for "several yards together."

One day Sir George persuaded his coachman to try the contraption. The wind was just right, and off went the coachman across the valley in a magnificent glide of some three hundred yards. Unhappily the plane was smashed in landing. From beneath the wreckage the uninjured coachman sputtered, "Please, Sir George, I wish to give notice. I was hired to drive, not to fly." Which may explain why he was, after all, only a coachman!

LILIENTHAL AND CHANUTE

Otto Lilienthal, born in Anklam, Pomerania, in 1848, carried on the work begun by Cayley. Unlike Sir George, who believed in an engine-driven propeller, Lilienthal thought that flight would be achieved through the flapping of wings. In this he was mistaken; but he did an immense amount for the progress of aviation because he believed the problem was to be solved one step at a time. When men had learned to soar on steady wings as did the storks of Ger-



Courtesy of Soaring Society of America, Inc.

A GLIDER

Other airplanes depend for motive power on their engines. A glider, having no engine, depends on and takes advantage of rising currents of air, soaring as a gull or hawk soars, but directed and controlled by its pilot.

many, he reasoned, it would be time enough to apply power.

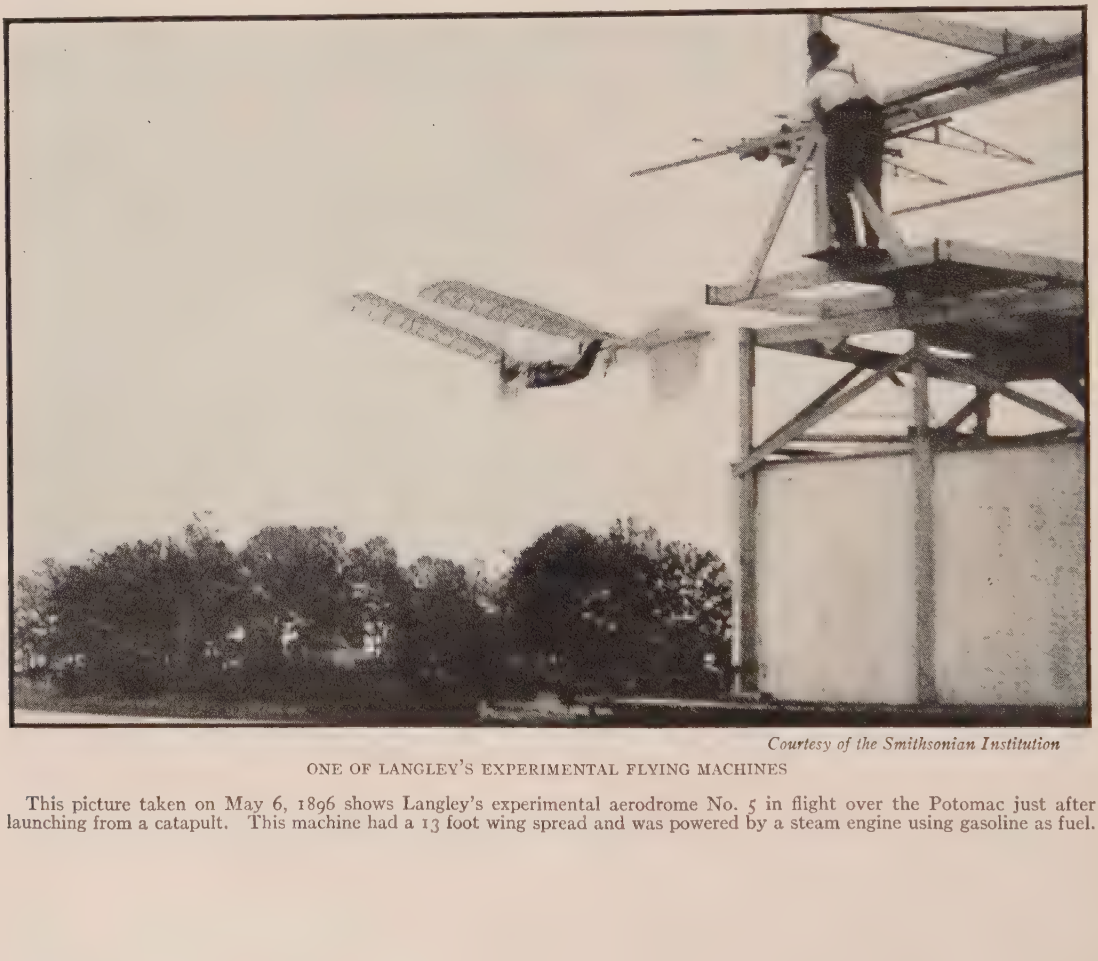
With the patient exactness of the German scientist, Lilienthal built his models, experimented with them, and recorded his data. He made thousands of glides, most of them from the top of an artificial hill he had caused to be built in the middle of a flat countryside. Thus, no matter what the direction of the wind, he could go on with his experiments. In 1896, after years of earnest, brain-racking work, he felt that he was ready to try out a power machine; but first he would make a gliding flight with it. Something went wrong with the controls, a fall of fifty feet broke his spine, and he never regained consciousness. Yet even at the age of forty-eight, death overtook him only after he had made a contribution of the very highest importance to aviation.

Octave Chanute, although a man in his sixties, carried on in America the work which Lilienthal had been unable to complete. Among the sandhills of Lake Michigan he experimented with various types of glider until he came to the conclusion that the biplane was best. Lilienthal had begun work in winds of eleven to thirteen miles per hour velocity. Chanute succeeded in making flights against a wind of thirty-one miles an hour, and his design was so excellent that even amateurs were occasionally allowed a trial flight.

It was Chanute who encouraged the Wright brothers, designed their first glider for them, and gave them the experienced services of his mechanic.

LANGLEY'S EXPERIMENTS

As Secretary of the Smithsonian Institution, Samuel Pierpont Langley occupied an important position among American men of science. The problem of flight so interested him that in 1898 he secured a Congressional grant of fifty thousand dollars for further experiments.



Courtesy of the Smithsonian Institution

ONE OF LANGLEY'S EXPERIMENTAL FLYING MACHINES

This picture taken on May 6, 1896 shows Langley's experimental aerodrome No. 5 in flight over the Potomac just after launching from a catapult. This machine had a 13 foot wing spread and was powered by a steam engine using gasoline as fuel.

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THE WRIGHT BROTHERS AND THEIR SISTER, MISS KATHARINE WRIGHT

Photograph taken on board the steamer upon the return of the aviators from their triumphant visit to Europe in 1908–1909. Besides winning many important prizes, the Wrights established new records for distance and duration flights and for high flying. In Spain they were received by King Alfonso, who inspected their machine and watched several flights. The king of Italy and the king of England also expressed warm interest in their performance. The admiral of the Italian navy and several officers of the army accompanied Wilbur Wright in exhibition flights near Rome.

This was only after two years of dogged effort by himself. When he had succeeded in building a model that would fly for half a mile, he turned to the development of the full-sized machine. To Charles Manly, a young Cornell graduate, was entrusted the design and construction of the engine, and so good a job did he do that after more than a quarter century airplane engines are still being built along the major principles which he laid down.

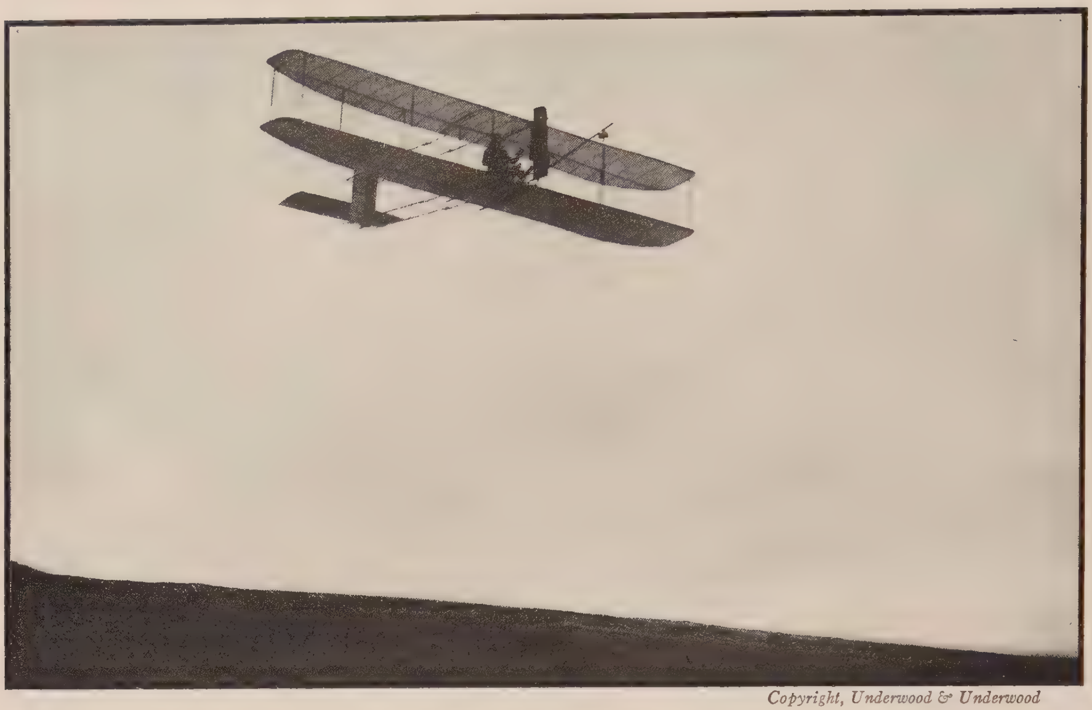
The Langley planes, or "aërodromes" as they were called, were launched from the roof of a house boat on the Potomac River, always with Manly as aëronaut. But no matter how hard the men tried, the planes always slid into the water like a load of slats and cast iron. Langley's efforts deserved a better reward.

THE STORY OF THE WRIGHT BROTHERS

The dream of the early ages, the power to soar through the air on real wings, came true through the inventive genius and daring of the two Wright brothers, Orville and Wilbur, who began to try their wings at Dayton, Ohio, who later found freedom from crowds among the sand dunes of North Carolina, and who finally flew in the first real flying machine that the world ever saw. For over two years they studied control and stability by flying gliders. They learned to prevent their machine from tipping sidewise by warping the wing tips, and they had the first practical flying machine.

In all history the names of the Wright brothers will go down as the inventors of the first real airplane. It was in 1900, the first year of the twentieth century, that these two young men began the work which was to make them famous.

At their bicycle shop in Dayton they made gliders after the plans of Lilienthal, Pilcher, and Chanute, and did their best to learn to fly with them. Chanute, who was in Chicago at the time, gave them much good advice out of his long experience, but they found in their home town little but ridicule and unbelief. To make a flying machine was in the minds of many as bad as to attempt to invent perpetual



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THE WRIGHT MOTORLESS GLIDER

Orville Wright trying out the new glider at the Kill Devil hills. In perfecting this machine the Wrights achieved one of their first great successes.

motion. The ridicule and skepticism to which they were subject is but the penalty which all people who are in advance of their age have to undergo, but it was not pleasant and it made their work more difficult. As they needed secrecy and a better field for trying out their experiments, they went down into a wild part of North Carolina. Among the Kill Devil hills they found sandy stretches of barren country where they were secure from all interruption.

There they worked patiently, building carefully with such tools as they possessed, trying out each new device with scrupulous care, methodical, patient, hard-working young inventors in whose lexicon there could be no such word as "fail." It was in 1900 that they began, and so slow and careful was their progress that it was not until two years later that they succeeded in making a glide of three hundred yards. In doing this they had brought the glider to a pitch of mechanical perfection and stability never before reached. But they had done more than this. Each had become far more skilled in the management of the machine, the instinctive balance and automatic foresight necessary for successful flight, than any other man who had attempted flight with a heavier-than-air machine. Out in the wilds of the Carolina hills the Wrights had the best gliding machine which the world had yet seen, and were themselves masters of the air, having that instinctive feeling for safety in flying which the bird has and which is one of the most important traits of the bird man.

THE FIRST MOTOR-DRIVEN MACHINE

The next year was to see a great advance in their experiments. They fitted a small motor and a propeller to their glider, and began to learn the game all over again with the same methodical persistency they had always displayed. Here was a whole series of new problems to be solved, and each must be solved under penalty of probable death. In the invention and improvement of most machines a failure means simply vexation and more work.

But a failure in the placing of their engine and in the construction and operation of their propellers meant grave danger for the daring inventor who should try to fly with the new appliances. The brothers went at this work as keenly and methodically as they had attacked the gliding problems, and they succeeded in the same way. But they worked two years more in such seclusion as they could command, striving steadily to perfect their invention before the world should find them out. And in a large measure they succeeded. In 1905 the startling fact was published that these two unknown inventors, working in secrecy in the Carolina hills, had made a flight of twenty-four and a half miles. Up to that time occasional reports had been printed that they had made successful flights, but the public was slow to believe this.

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THE WRIGHT AIRPLANE IN FLIGHT

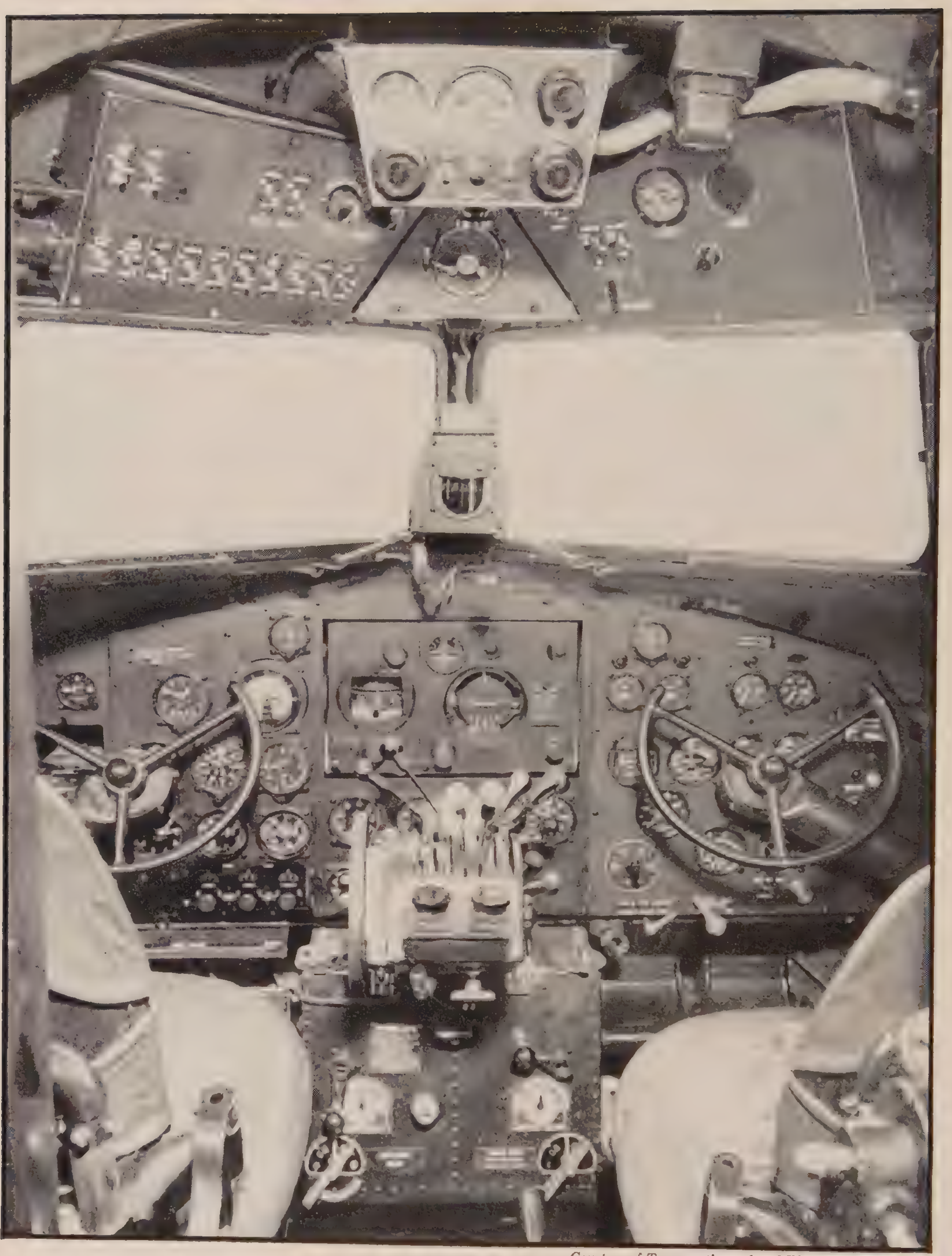
This photograph was taken less than one minute before the accident occurred.

The lack of confidence which the inventors had experienced in Dayton was for a time their portion in the wider world. But this did not trouble the Wrights. They were as serene through all this as they were later when no praise was too great for their astonishing feats — types of that modest, self-reliant American manhood which has always been deemed worthy of the highest praise. Down in the wilderness of the Kill Devil hills, with only the simplest appliances and tools, they brought their original machine to a high pitch of mechanical perfection.

WINNING THE FIRST PRIZE

It was in 1905 that the tide of popular approval turned in favor of the Wright brothers. For a time no one had seemed to believe in them. Now the world was all agog with prophecies of the great things which were to come from aviation. In most civilized countries inventors were experimenting with flying machines, and the Wrights were obliged to stop flying and experimenting on flying machines to attend to business negotiations in regard to the use of their patent rights. Thus time passed swiftly by, and it was almost three years later, in the spring of 1908, that they began tests again. They had improved and increased the power of their motor and had agreed to furnish a machine for the United States Signal Corps and one to a French syndicate.

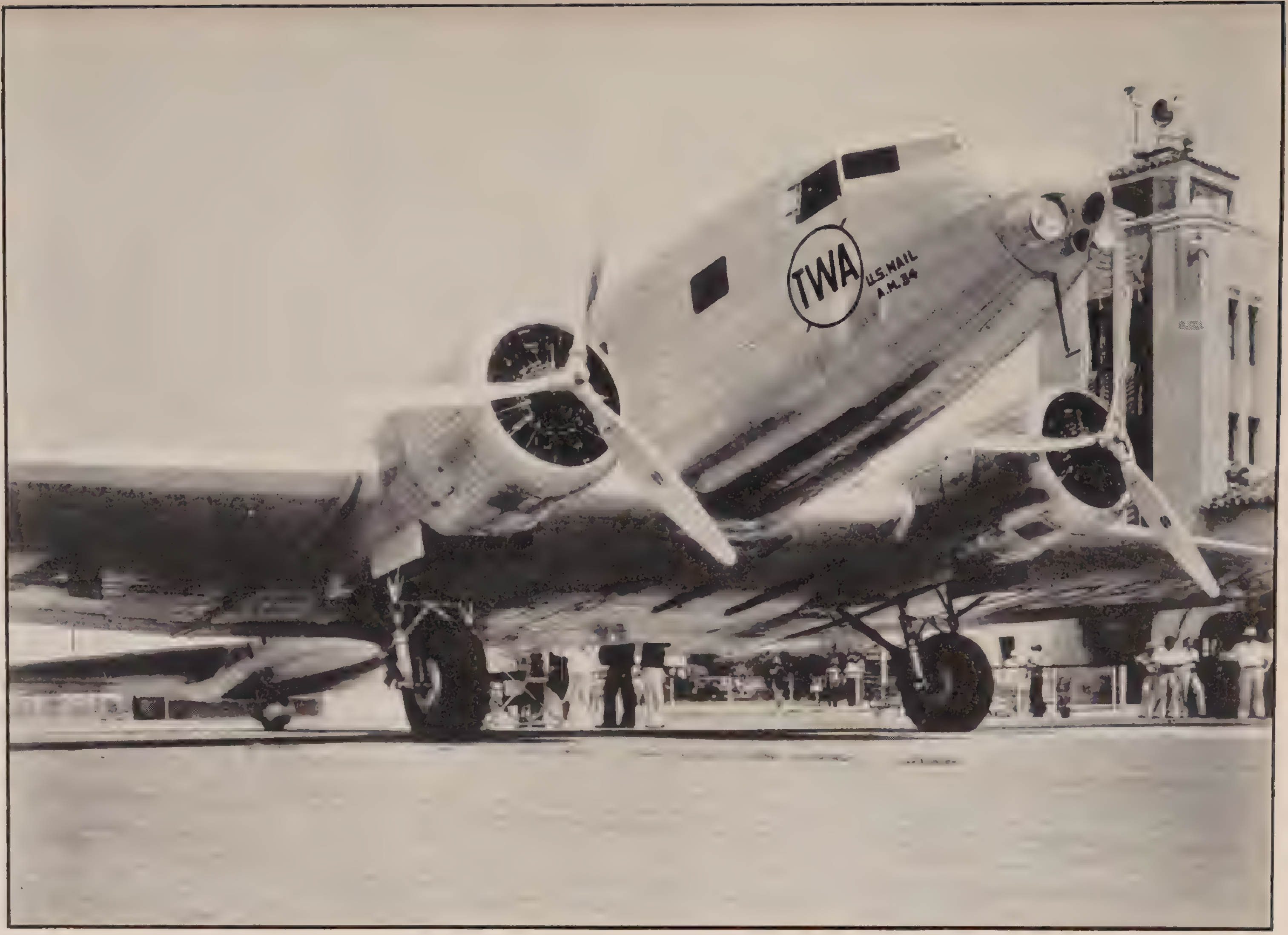
The machine which was to be furnished for the Signal Corps must be able to carry two men and to fly for one hour without stopping at an average speed of forty miles per hour. This flight must be made across a rough country, dotted with hills and valleys, forest and open field. Another requirement was that the machine should prove that it could go 125 miles without stopping. The Wright brothers agreed to furnish such a machine for $25,000, and Orville Wright went to Fort Myer, Va., near Washington, to complete the test under the conditions as specified by the government.



Courtesy of Transcontinental and Western Air, Inc.

PILOT'S COMPARTMENT OF AN AIR LINER

There are more than seventy-five gauges, switches, warning lights and various controls to aid the air line pilots in operating their planes.



Courtesy of *Transcontinental and Western Air, Inc.*

TRANSCONTINENTAL PLANE AT A COMMERCIAL AIRPORT

A "low winged" monoplane which carries passengers, mail and express from coast to coast at almost unbelievable speed. An idea of the size of this ship may be gained by comparing it with the passengers waiting to embark.

Acme Photo: The Outlook

COLONEL CHARLES A. LINDBERGH AND "THE SPIRIT OF ST. LOUIS"

His flight from New York to Paris on May 20–21 was the event of the year 1927. He flew alone across the Atlantic, 3610 miles, in 33½ hours. This achievement won the acclaim of the governments and peoples of the world and stimulated lagging interest in aviation.

IN THE AIR FOR AN HOUR AND THREE MINUTES

The world, once disbelieving, was now wildly enthusiastic. Thousands flocked into the drill-ground to see this first public appearance of the noted young inventors and their marvelous machine.

The preliminary flights were successful in all particulars, and in the final test Orville Wright flew the machine an hour and three minutes. Later, for the first time in America, he took a passenger in the air. Lieutenants Lahm and Selfridge were each thus favored with short flights.

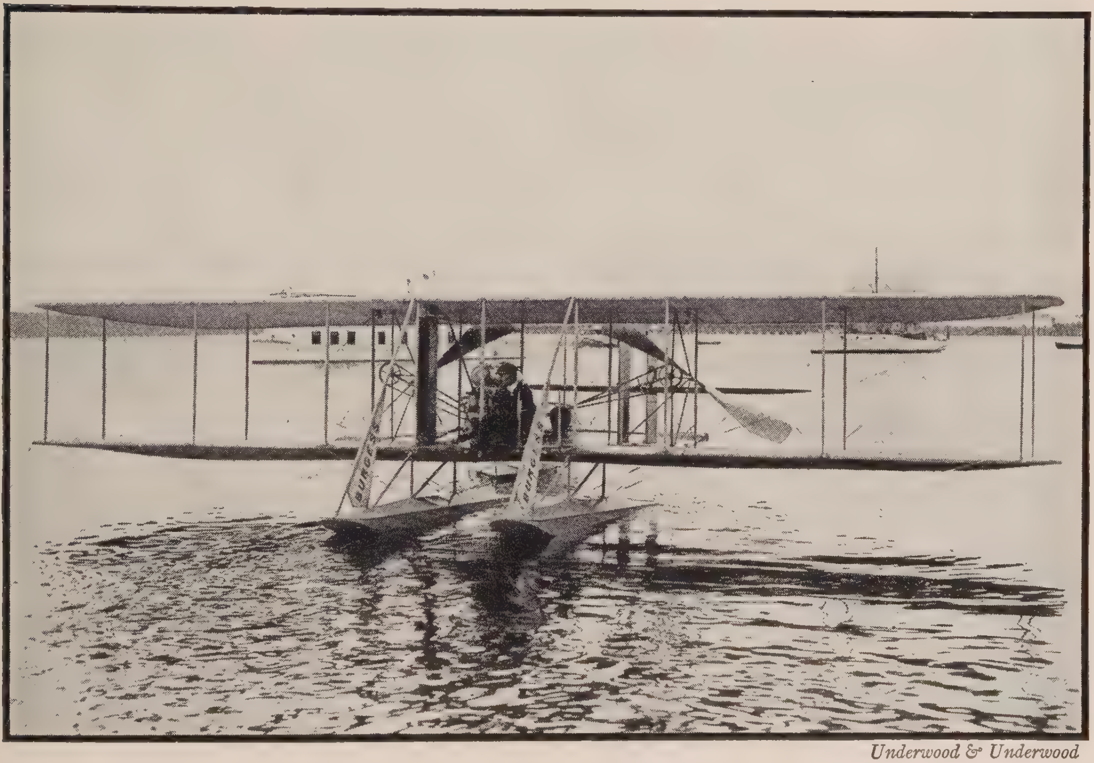
The triumph of the Wright brothers was great and well deserved. The newspapers the world over devoted pages of space to the men, their machines, and the wonderful new power thus given to mankind, the dream of the ages being fulfilled at last in actual flight. Somewhat later the world was shocked by the first fatal airplane accident in America. Orville Wright was in France, exhibiting a machine at Le Mans; Wilbur Wright at Fort Myer continued to make ascents. One day he was about seventy-five feet in the air with Lieutenant Selfridge when one of the stay wires on his machine broke, wrapped around the propeller, and the machine, no longer under control, plunged to the ground. Lieutenant Selfridge was killed and Wright had several bones broken. The machine had, however, before this accident completely fulfilled all tests, and the United States was the first nation officially to adopt an airplane for military purposes.

THE WORLD AVIATION MAD

Soon the world began to go aviation mad. The new science fascinated participants and observers alike. Inventors in every land were at work on all sorts of machines, and aviation meets began to be held everywhere, in which daring acrobats of the air showed marvelous skill in the management of the new machines. Crowds of scores of thousands watched competition in flight over measured courses with keen delight in the racing, large sums of money were offered for prizes to the aviator rising to the greatest height or making the longest cross-country trip, and in countless other ways the new sport was encouraged. In many of the most important of these meets the Wrights took part, being often victors.

Everywhere schools of aviation were started, and the number of aviators began to be legion. Besides the Wrights, great names of the day in aviation were Curtiss, Blériot, Farman, Latham, Paulhan, and many others who took part in the first great international meet at Rheims. There Curtiss won the speed prize in a sixty-horse-power biplane of his own make, in two rounds of the field at a rate of 47.04 miles per hour. This speed was acclaimed at the time as wonderful, though now, but a few years after, speed records make these early achievements interesting only by contrast. The first altitude prize at an early meet was won by Wilbur Wright, with a record of 361 feet. At the first Rheims meet the distance prize, the "Grand Prix de la Champagne" of $10,000, was won by Farman, flying patiently in his slow biplane 68 miles.

So the record of increased power and stability in the machines increased almost daily, as well as the skill evinced by aviators. Great credit is due to many inventors — Curtiss, Langley,



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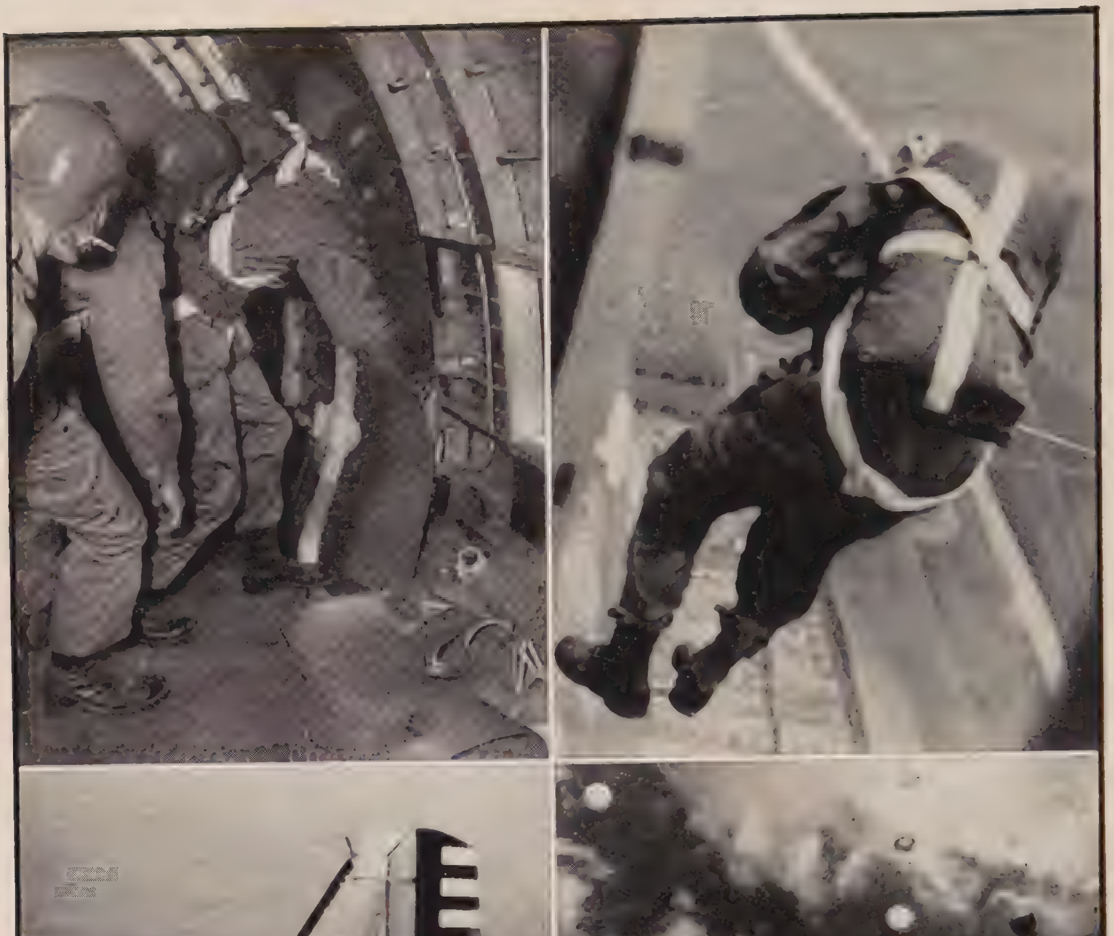
AN EARLY WRIGHT PLANE WITH PONTOONS

Note the two propellers, chain-driven by a single engine.



Official Photographs, U. S. Army Air Forces

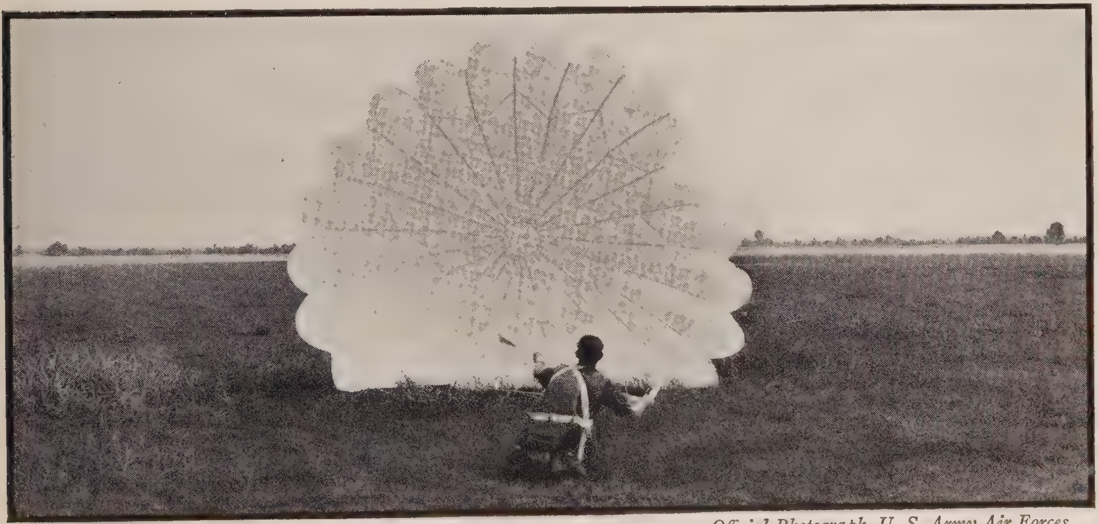
U. S. ARMY PARACHUTE TROOPS IN ACTION

Herring, Bell, Baldwin, McCurdy — and particularly the Wrights in this country, while abroad a great host of inventors and experimenters have aided in planning and perfecting scores of varieties of machines. One cannot attempt to name them all. Santos-Dumont was a pioneer in flight by means of the airplane, just as he had been a pioneer in the use of dirigibles. Indeed, authorities agree that his was the first free flight of a power-controlled flier ever publicly seen in Europe. Two years before that a man by the name of Ader is said to have flown a machine in secret, but the flight of Santos-Dumont was made before several thousand people. Two months later, in October, 1906, he made a flight of 221 meters in 21 seconds, winning the Archdeacon Cup of two thousand francs authorized by the Aëro Club of France for a flight of 100 meters. This was a year after the Wrights had made their flights alone in the Carolina wilderness.

In 1907 the Voisin brothers finished a biplane in which Henri Farman and Leon Delagrange astonished the world. Then Blériot succeeded in flight with his monoplane, which has ever since remained a splendid type of swift flier. Blériot made failure after failure in his attempts to build a successful machine from 1900 until 1908, but in October of the latter year he made a cross-country flight of seventeen miles, the second ever attempted, Farman in his biplane having done about the same distance the day before. Blériot was the first man to cross any long stretch of open sea, his cross-channel flight giving him world-wide fame.

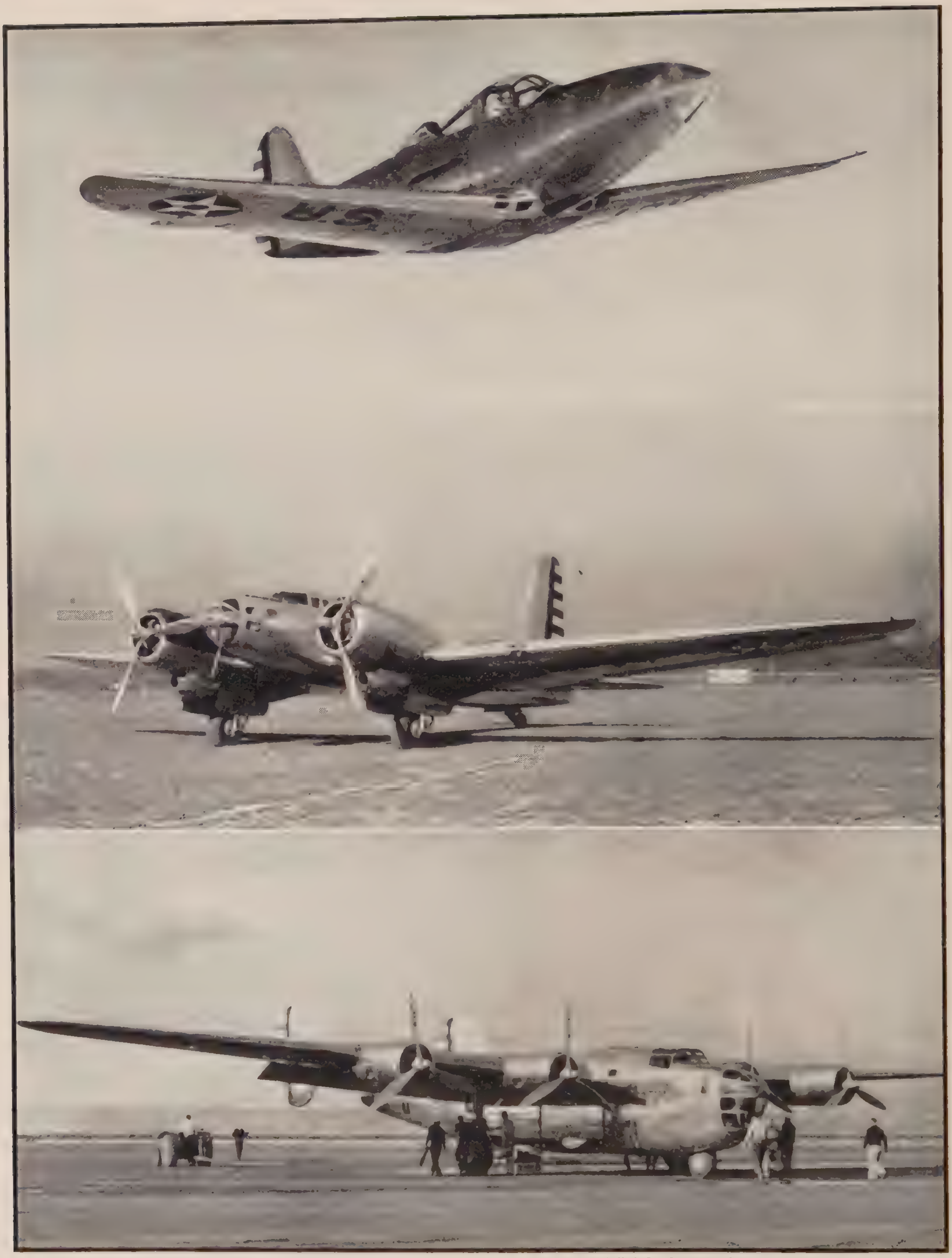
CROSSING THE ENGLISH CHANNEL

The London *Daily Mail* offered a prize of five thousand dollars for the first aviator to cross the English Channel. The French aviator Latham narrowly missed winning this prize, but fell in mid-channel, being rescued with his machine by an attendant tug. Then Blériot tried it. The plucky aviator had been severely burned by a gasoline explosion just a few days before and could barely hobble on crutches. Nevertheless, he bade his attendants lift him into the machine. "I'll show them that I can fly if I cannot walk," he said, and in a few moments he was sailing through the air over the Channel at a rate that soon left the swiftest attendant torpedo boats behind. The day was fair and the wind gentle. The intrepid airman was out of sight of both coasts for a matter of perhaps ten minutes. Then the white chalk cliffs of Dover appeared, and soon afterward he alighted safely on English soil, to be welcomed by a newspaper reporter and two policemen! The English were finishing their Sunday morn-



Official Photograph, U. S. Army Air Forces

"SPILLING THE WIND" FROM THE CHUTE ON LANDING



Official Photographs, U. S. Army Air Corps

MILITARY AIRPLANES

Top: A pursuit plane. Middle: A twin-motored medium bomber. Bottom: A four-motored heavy bomber.

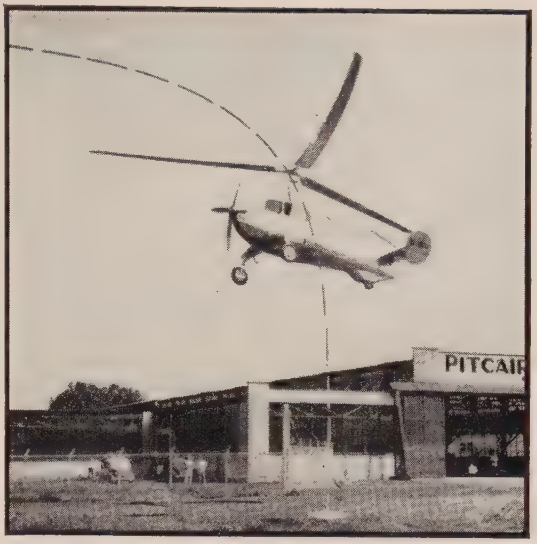
ing naps! Still it was the great aviation feat of the day, and his success was flashed around the world by telegraph and cable, and was acclaimed in all lands.

This was in the summer of 1909. Since then, feats have been accomplished in aviation before which this seems the veriest commonplace. Airplanes have flown around the world, over both Poles and over the summit of Mount Everest, the highest mountain in the world. Back in 1911, when the American continent was first crossed by airplane, fifty days of elapsed time and eighty-two hours of actual flying time were required. Now anyone can travel in a luxurious passenger plane from the Atlantic to the Pacific in a day or a night.

Aviation has moved forward by such leaps and bounds that it is hardly safe to record any figures or to give any but general statements. Still, remembering those early flights at the first International Meet at Rheims in 1909, when Curtiss won a first prize for flying twelve miles at the rate of forty-six miles an hour, we should stop a moment to marvel at today's airplanes. Today there are airplanes which travel faster than a rifle bullet and others which regularly cross the oceans with huge loads of passengers and mail. Even the human limitations are now removed. Formerly aviators lost consciousness at high altitudes because of the cold and lack of oxygen. Now they ride comfortably in enclosed, heated cabins and either carry tanks of oxygen to breathe or else have their ships equipped with superchargers which build up the air pressure inside the cabin so that it is never too rarified for comfortable breathing.

MILITARY AVIATION

The World War of 1914-1918 gave an enormous stimulus to the development of the airplane, which was first used only to see with, then to communicate with, and last of all to fight with. Stunts which seemed wildly reckless in 1914 were a necessary part of every pilot's flying knowledge a year later. The planes which were being built at the end of the war, while they would seem slow and cumbersome today, were many times faster, more powerful and more maneuverable than those used at the beginning. Also the war gave the world a large number of experienced and enthusiastic airmen who carried on the development of aviation in peace time and who kept preaching the importance of the airplane as a military weapon.



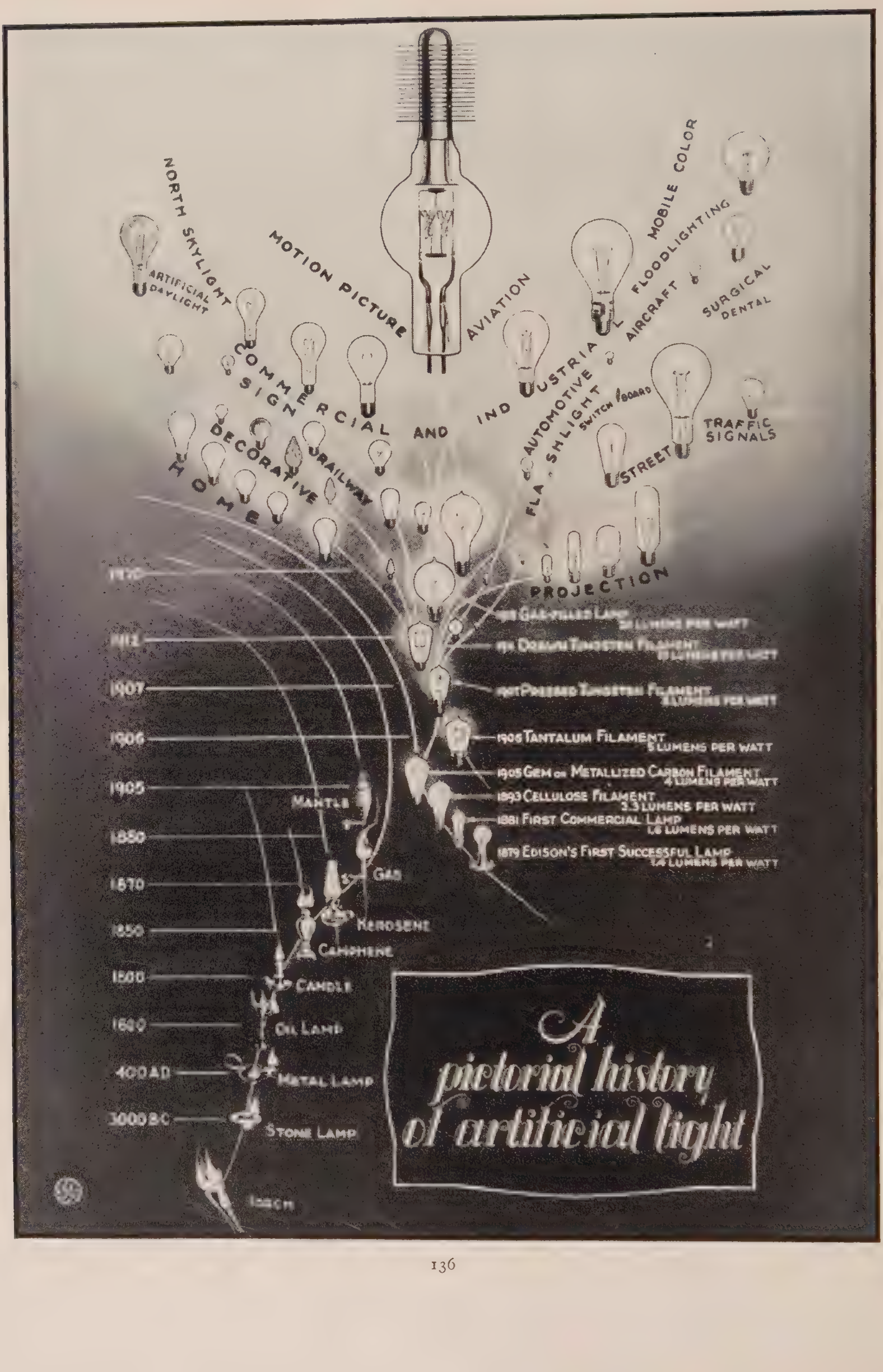
Courtesy Pitcairn Autogiro Co.

AN AUTOGIRO

Invented by a Spaniard, Juan de la Cierva, the autogiro can take off and land vertically. It has no fixed wings. The lift is supplied by a large three-bladed rotor atop the cabin. This rotor is powered by the motor only for the jump take-off. In flight the rotor is kept spinning by the forward motion of the ship through the air. When on the ground the rotor blades can be folded back over the fuselage, the power applied to the rear wheel and the ship driven along a road like an automobile. The broken line shows the path of the jump take-off.

Today control of the air is considered absolutely necessary for the success of any military action, either offensive or defensive, and this is equally true on land and on sea. Germany's huge air force gave her a big advantage when the second World War broke out in 1939 and accounted in large measure for her amazingly rapid series of conquests on the continent of Europe. On the other hand, England's smaller but highly efficient Royal Air Force was an equally important part of her defense against invasion. The United States, profiting by the lessons of the war, has determined to have an air force second to none and is spending many million dollars every year for the building of planes and the training of men to fly them.

(The story of how the airplane has found its place in the commercial life of the world is told in Volume Four, pages 360 to 363.)



A pictorial history of artificial light
NORTH SKYLIGHT
ARTIFICIAL DAYLIGHT
MOTION PICTURE
AVIATION
MOBILE COLOR
FLOODLIGHTING
AIRCRAFT
SURGICAL
DENTAL
COMMERCIAL AND INDUSTRIAL
SIGN
AUTOMOTIVE
FLASHLIGHT
SWITCHBOARD
STREET
TRAFFIC SIGNALS
DECORATIVE
RAILWAY
HOME
PROJECTION
1913 GAS-FILLED LAMP
LUMENS PER WATT
1911 DRAWN TUNGSTEN FILAMENT
LUMENS PER WATT
1907 PRESSED TUNGSTEN FILAMENT
LUMENS PER WATT
1906 TANTALUM FILAMENT
5 LUMENS PER WATT
1905 GEM OR METALLIZED CARBON FILAMENT
4 LUMENS PER WATT
1893 CELLULOSE FILAMENT
3.3 LUMENS PER WATT
1881 FIRST COMMERCIAL LAMP
1.6 LUMENS PER WATT
1879 EDISON'S FIRST SUCCESSFUL LAMP
1.4 LUMENS PER WATT
1930
1911
1907
1906
1905
1880
1870
1850
1800
1600
400 AD
3000 BC
MANTLE
GAS
KEROSENE
CAMPHENE
CANDLE
OIL LAMP
METAL LAMP
STONE LAMP
TORCH

Wide World Photos, Inc.

ARMY SEARCHLIGHTS TOTALING TWENTY BILLION CANDLE POWER

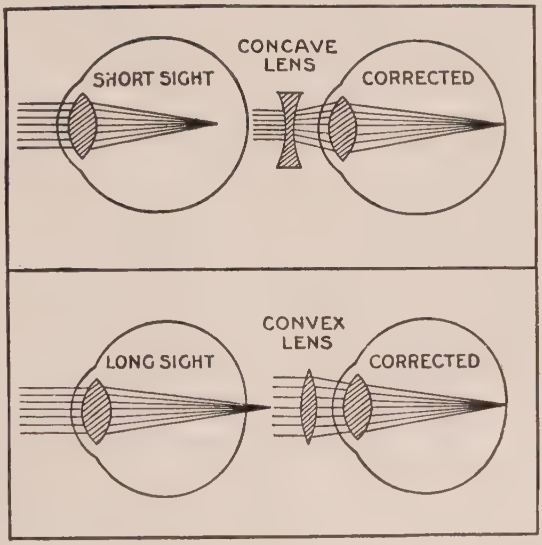
THE MIRACLE OF LIGHT

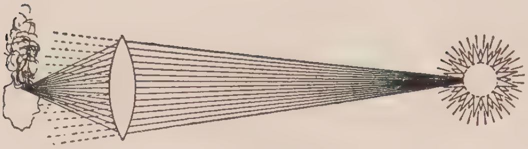
ONE of the great miracles of existence is light. Scientifically speaking, light consists of vibrations in the ether which fills all space. The sun, which is the great source of our light, sends it to the earth at the rate of 186,000 miles in a single second. Only the lowest forms of life can get on without light, and without direct sunlight the higher forms fade and die. It is one of three great wonder workers which may have the same source and of which the other two are heat and electricity. Chief among the marvels produced by light is the adaptation of animal and plant life to receive it and benefit by it. Of these adjustments none are more wonderful than those made by that delicate mechanism, the human eye.

THE MARVEL OF THE HUMAN EYE

The eye is a wonderfully adaptable hollow ball, with a window in the front and the hollow filled with a transparent liquid. It also contains a focusing screen by means of which the sight is adapted to things near or far, as the will of the brain behind the eye may direct. A special nerve carries the image which comes through the lens to the brain, and thus the person sees. It is quite like the working of a splendid self-adjusting camera, the picture remaining for a little space of time on the brain after the lens ceases to produce it.

But sometimes the round lens of the eye is not of quite the right shape for perfect vision. It may be too spherical, and then the person cannot see things at a distance well. The lens is out of focus there. It may be too flat, giving splendid vision at great distances but blurring things, out of focus again, near to. So, long ago, people who made things of glass found that a glass lens could be put before the eye that would correct these misfortunes in eyesight. Above are some diagrams of the





A BURNING GLASS CONCENTRATING THE HEAT RAYS WHICH FALL UPON IT

eye and its lens and the glass lens in front of it, showing how the glass catches the parallel rays of light and makes them focus just right on the retina of the eye, which is the screen whence the nerve takes the picture to the brain. Thus eyeglasses or spectacles were invented, and they have been a great boon to mankind ever since.

The common burning glass shows well how the heat as well as the light rays from the sun are focused. If you hold this at just the right distance away from a piece of paper, it will set it afire, but if you hold it too near or too far, so that the paper is not in focus, nothing happens.

THE MICROSCOPE

The burning glass may be used as a reading glass, for if held at just the right place above a printed page, it makes the letters all look much larger, and in this we have the first principle of the microscope. By an arrangement of many lenses in a suitable frame we can thus magnify objects almost indefinitely, and things which are far too small to be seen at all by the ordinary eye are enlarged hundreds or even thousands of times and can be plainly seen and studied. By the use of the microscope scientists have conferred great benefits upon mankind. They have found and studied the exceedingly small germs of various diseases and learned how to destroy them, thus saving people from dangerous and deadly diseases which were once almost always fatal. In this one thing alone the value of the microscope to human life is incomputable.

SIMPLE LENSES

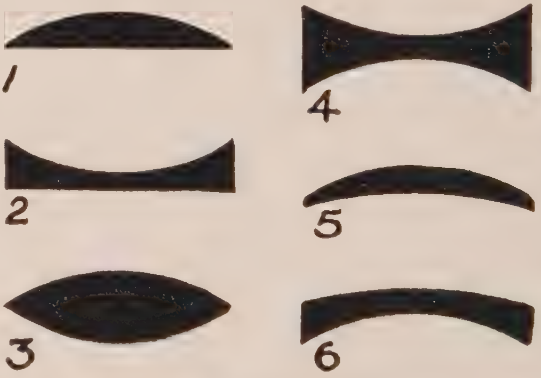
In the illustration are shown six forms of simple lenses such as are used in spectacles and in microscopes, telescopes, and cameras.

Nos. 1 and 2 have one flat and one spherical surface. Nos. 3, 4, 5, and 6 have two spherical surfaces. When a lens is thicker at the middle than at the sides, it is called a "convex" lens; when thinner, a "concave" lens. The names of the various shapes are as follows: No. 1, plano-convex; No. 2, plano-concave; No. 3, double convex; No. 4, double concave; No. 5, meniscus; No. 6, concavo-convex. The thick-center lenses, as we may term them (Nos. 1, 3, 5), *concentrate* a pencil of rays passing through them; while the thin-center lenses (Nos. 2, 4, 6) *scatter* the rays.

GLASSES THAT SHOW US WORLDS

Galileo invented the telescope in 1609. He found that by putting lenses of a certain kind in a tube and moving them nearer together or farther apart he could get things at a distance in focus and see them very clearly and apparently magnified. Opera glasses, so commonly used to-day, are built on the Galilean principle. Galileo has the credit for this invention, for he made the best telescope of his time and with it made important discoveries in astronomy; but the idea was not new at the time, nor indeed was he the only man of his day to make a telescope. Other men during that same year of 1609 were at work on telescopes exactly like Galileo's, among them being Lippershey, Janssen, and Messier. However, Galileo made the best and made the best use of it, so he fairly deserves the credit. No one knows who first got the idea. Roger Bacon wrote about it in 1250, more than three hundred and fifty years before Galileo's day.

A hundred years after Galileo, Sir Isaac Newton made a reflecting telescope, an instrument



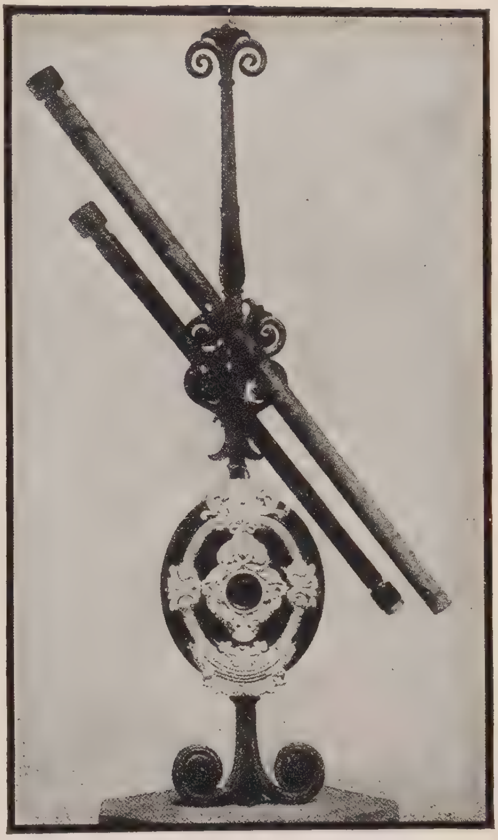
FORMS OF SIMPLE LENSES

containing a mirror as well as lenses, which was a great improvement on that of the original inventor, and since then men the world over have been making bigger and more perfect telescopes. The world's largest and most active telescopes are in America. Galileo's telescope magnified three times, and he made discoveries with it that were wonderful for his day. It was the size of the ordinary spyglass which one holds in one's hand. Just compare it with the refractor at the Yerkes Observatory, near Chicago, which has an object glass forty inches in diameter, or that at the Lick Observatory in California with its thirty-six inch glass. A number of observatories have refractors with object glasses more than twenty inches across.

The great reflector first used at the Paris exposition of 1878 was the wonder of its time. Its mirror had a diameter of fifty-nine inches and was mounted in a tube one hundred and eighty feet long. Several reflectors were later built with mirrors sixty inches or more across. The one-hundred inch reflector at the Mt. Wilson Observatory near Pasadena, California was for many years the largest in existence. (The picture on page 141 gives an idea of its great size.)

However, scientists desired to reach even farther into the unexplored regions of space, and in 1934 work was begun on a two-hundred inch reflector telescope which will eventually be installed in a new observatory on Mt. Palomar in Southern California.

At the famous glass works at Corning, New York, twenty tons of special Pyrex glass (the largest piece of glass ever made by man) were molded into a huge disc nearly seventeen feet in diameter and twenty-seven inches thick. As this disc could have been ruined by too sudden cooling, the heat of the molten glass was reduced so gradually that it required nearly a year to cool it to room temperature. After careful inspection showed the disc to be free from flaws it was shipped to California to be ground and polished to mirror form. Grinding and polishing of the mirror is an extremely tedious and delicate process, requiring about four years for completion.


GALILEO'S TELESCOPE

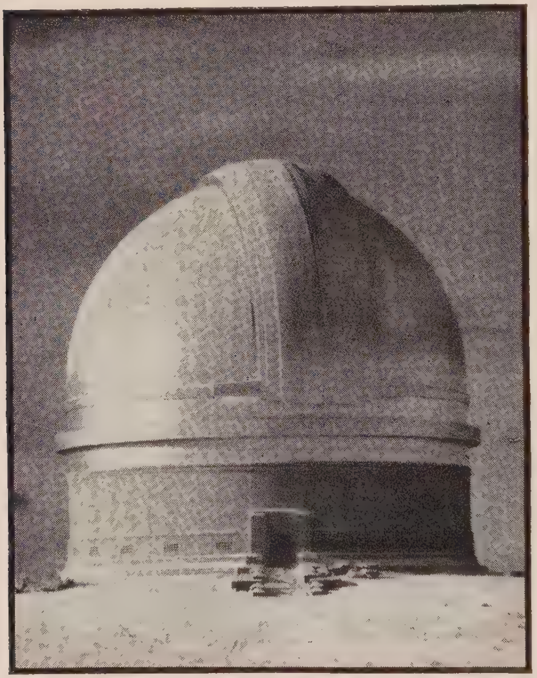
About four tons of glass must be ground off the big disc and the final polishing must be accurate to the almost unbelievable figure of one-millionth of an inch. A mirror surface must then be obtained. This will not be the familiar "silvered" surface, but is to consist of a coating of aluminum deposited on the glass by a process of evaporation of the metal.

The two-hundred inch mirror will be installed in the world's largest telescope, the weight of which, exclusive of its stationary mountings, will be almost five hundred tons. It will gather four times as much light as the Mt. Wilson reflector, exploring vast spaces never before seen by man, and revealing billions of stars heretofore invisible to the astronomer. With it our American astronomers may well make new contributions to human knowledge.

THE SPECTROSCOPE

To the human eye, unaided by any artificial instrument, light was able to bring wonderful stories of color, form, and movement. When man began to aid his vision by mechanical means he entered a new world of knowledge and experience. The microscope made the tiniest and most infinitesimal objects visible, revealing in a drop of water or a grain of earth a world which would have been without its use entirely unknown to him. The telescope brought the most remote objects in man's universe to an appearance of comparative nearness. It remained for the spectroscope to translate into signs which scientists could learn to read the stories that light could tell of the physical and chemical composition, the temperature, and the rate of speed of worlds a million miles away.

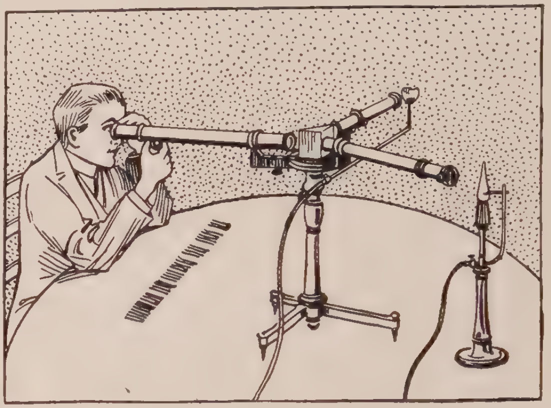
In "The Earth A Storybook," Volume I, pages 102–108, is told the story of the make-up of a ray of light, as revealed by the prism, through which the different vibrations are thrown on the screen in the familiar spectrum of rainbow colors. From this simple experiment and the consequent identification of the solar spectrum came the intricate modern science of spectroscopy, a science founded on the study of the spectra of light-giving bodies.



Courtesy, Calif. Inst. of Tech.

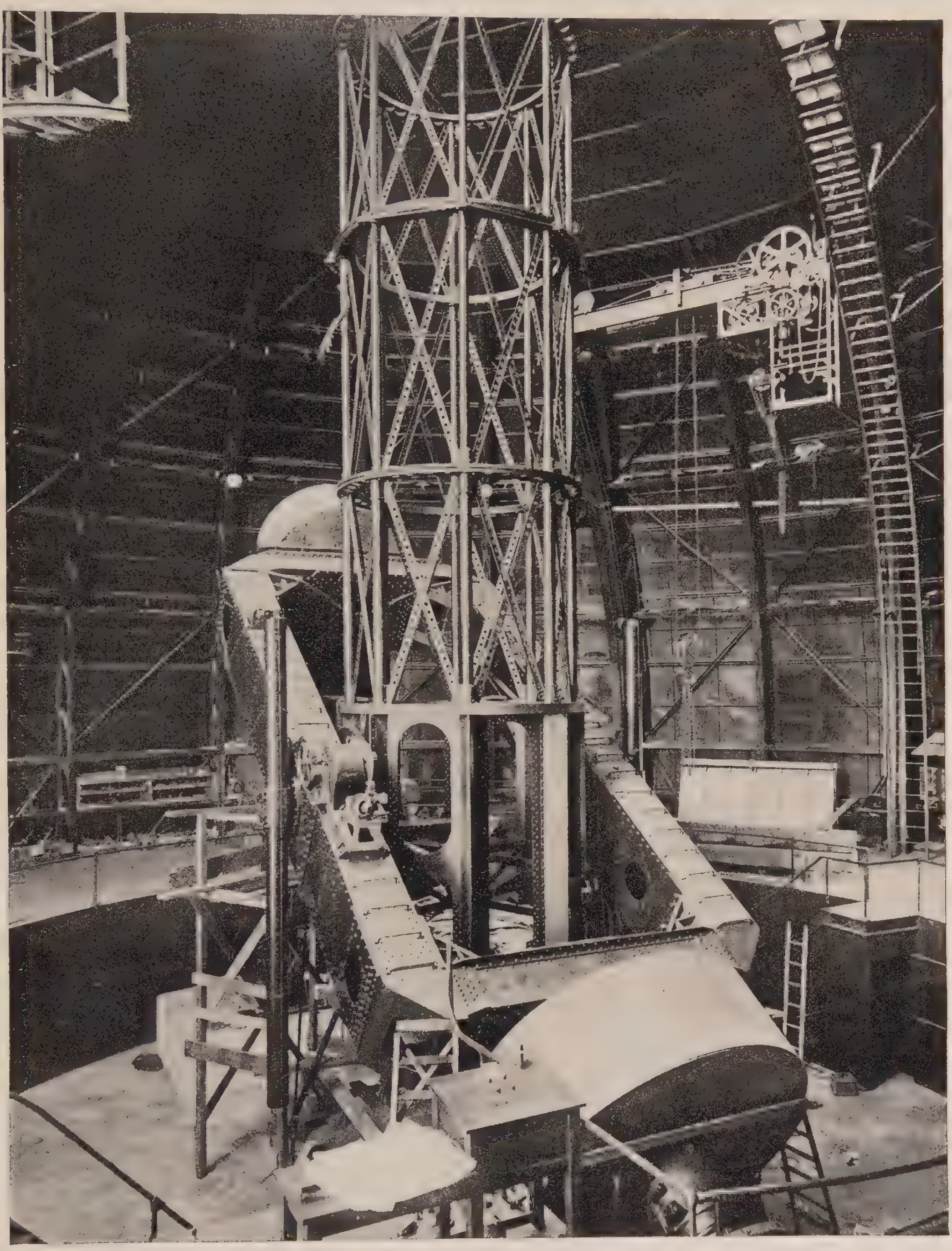
THE MOUNT PALOMAR OBSERVATORY, CALIFORNIA

The spectroscope is an instrument consisting, in its simplest form, of a plate of metal with a very narrow slit in it through which light enters, a tube containing prisms or gratings by which it is [broken up or "dispersed," and a telescope to focus and magnify the spectrum.



USING THE SPECTROSCOPE

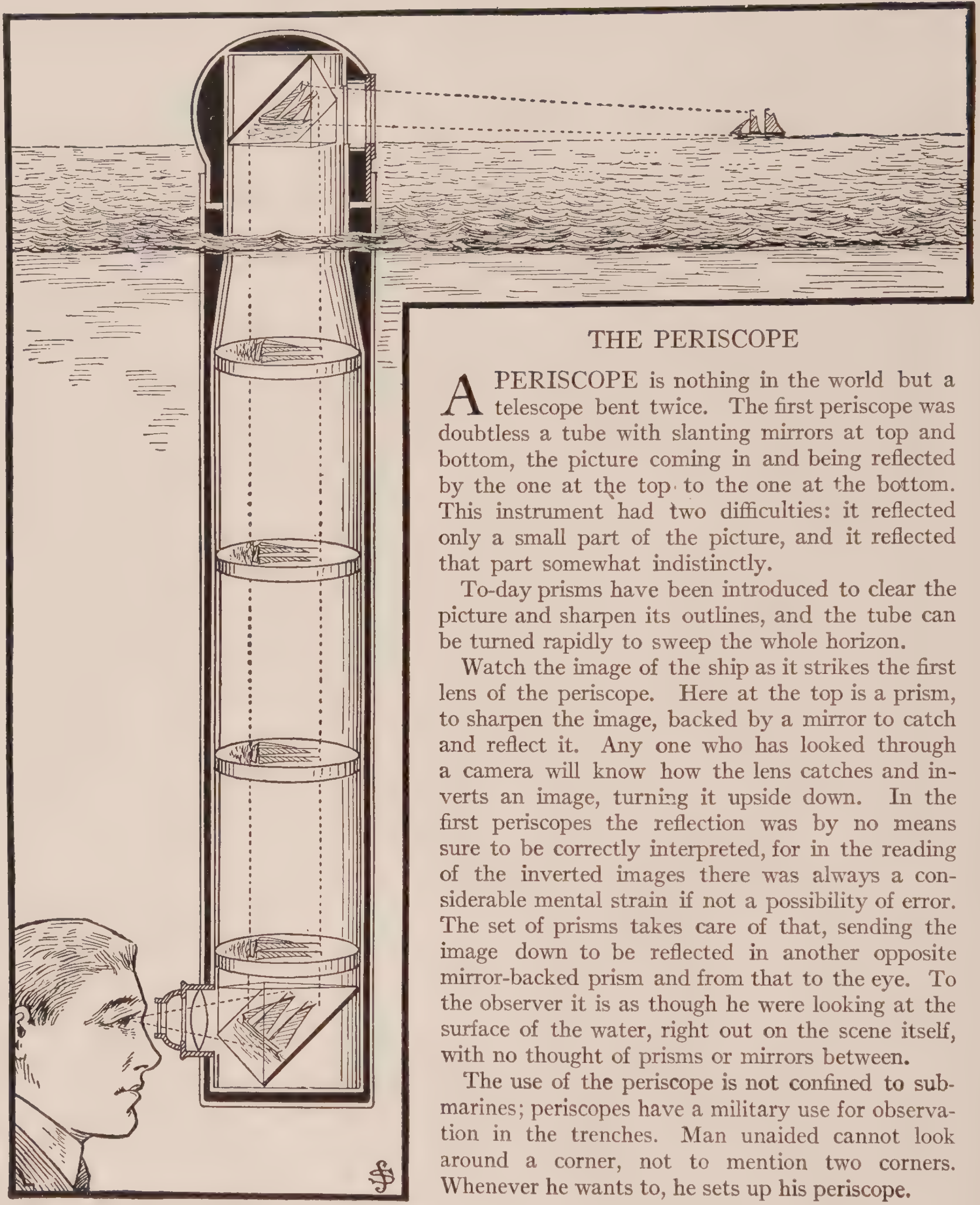
The light from different sources varies when shown by the spectroscope. Sunlight, for instance, has always its complete set of rainbow colors with which we are familiar. The story told by the strip of light from any luminous object is found to tell what the light-giving object is made of. Since each element has under the same conditions the same spectrum, and that spectrum is different from that of any other element, it is evident that if from a certain object you get the spectrum of a known element, you have proved the presence of that element in the object. For instance, the presence of certain features in the solar spectrum shows that the sun has in it sodium, iron, carbon, etc. The spectrum of a solid or liquid even at great heat is found to be continuous, without breaks, while that of gas consists of only a few bright lines. Therefore certain luminous objects in the heavens are easily identified as nebulæ, enormous clouds of glowing gas, while others are proved to be solid worlds. To be able without touching a substance to discover the elements of which it is made is to come as near to seeing the hidden things of Nature as any instrument invented by human ingenuity has yet attained.



THE 100-INCH REFLECTOR AT THE MOUNT WILSON OBSERVATORY, CALIFORNIA

See also Volume I, pages 40 and 64.

THE EYE OF THE SUBMARINE



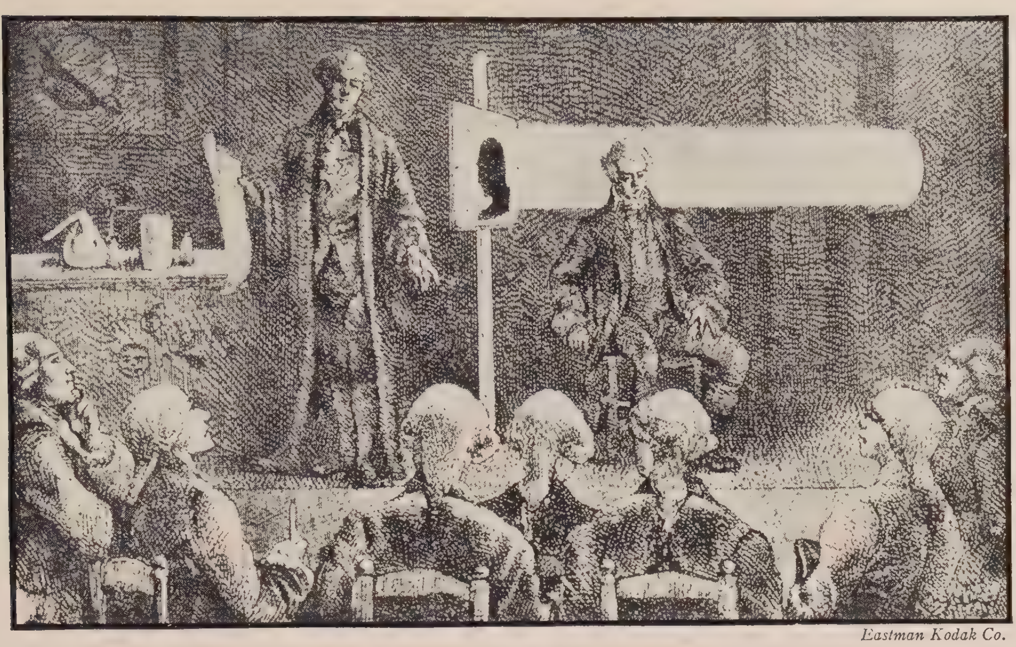
THE PERISCOPE

A PERISCOPE is nothing in the world but a telescope bent twice. The first periscope was doubtless a tube with slanting mirrors at top and bottom, the picture coming in and being reflected by the one at the top to the one at the bottom. This instrument had two difficulties: it reflected only a small part of the picture, and it reflected that part somewhat indistinctly.

To-day prisms have been introduced to clear the picture and sharpen its outlines, and the tube can be turned rapidly to sweep the whole horizon.

Watch the image of the ship as it strikes the first lens of the periscope. Here at the top is a prism, to sharpen the image, backed by a mirror to catch and reflect it. Any one who has looked through a camera will know how the lens catches and inverts an image, turning it upside down. In the first periscopes the reflection was by no means sure to be correctly interpreted, for in the reading of the inverted images there was always a considerable mental strain if not a possibility of error. The set of prisms takes care of that, sending the image down to be reflected in another opposite mirror-backed prism and from that to the eye. To the observer it is as though he were looking at the surface of the water, right out on the scene itself, with no thought of prisms or mirrors between.

The use of the periscope is not confined to submarines; periscopes have a military use for observation in the trenches. Man unaided cannot look around a corner, not to mention two corners. Whenever he wants to, he sets up his periscope.



Eastman Kodak Co.

AN EARLY EXPERIMENT

Making a silhouette on sensitized paper by means of a beam of light.

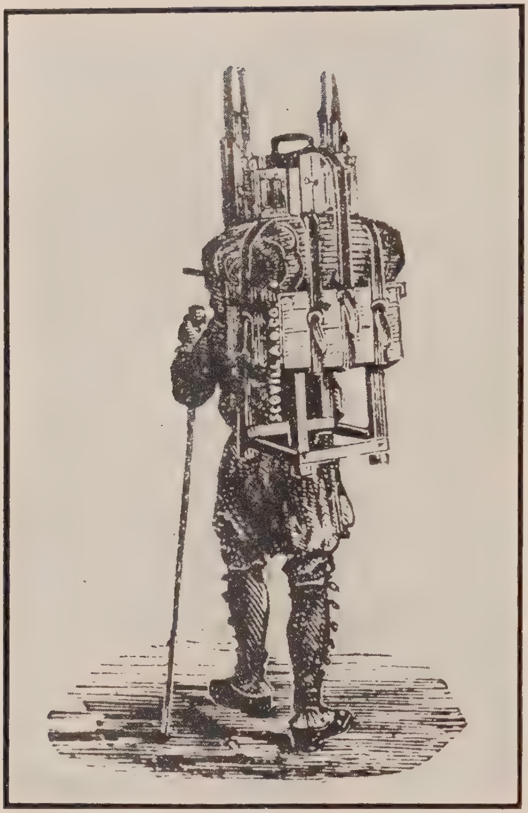
PHOTOGRAPHY

THE word "Photography" is derived from the Greek words meaning "light" and "to write," and when next you take a snapshot with your camera it will very likely have more than its usual amount of interest when you reflect that you are in reality "writing with light." As its name implies, photography has a very vital relationship with the theory of light. Since this is so, we can readily trace its connection with solar physics, spectrum analysis, chemistry, optics, and with electricity, too, since the field of medicine now relies so greatly upon the magic of the X-ray.

The uses of photography are apparently without end. Almost every year finds some new achievement added to its already fine record, from an astronomical photograph of the sun's eclipse or of some recently discovered planet to the use of color film so that natural color may be reproduced in the modern motion picture.

The ancients were not so careful as are we of the twentieth century to record painstakingly everything that occurs in order that posterity may have a record of human progress. For this reason we find it very difficult to determine just when the first principle of photography was definitely discovered. In all probability, however, the alchemist Fabricius was the discoverer, for it was he who in 1556 first noted the action of the sun's rays in darkening the color of the skin, or "tanning" as we call it. The beautiful coat of tan which you so proudly display after a happy summer at the seashore or in the mountains is just as surely the effect of solar radiation (sun's rays) as is the darkening of the sensitized film when we expose it in our camera to secure a picture. If by any chance you are an amateur photographer and have eagerly peered into a tray of developer to watch an image appear upon a film or plate, you will be interested to know that it took men over two hundred and fifty years to learn how to produce this result and almost three hundred years to make it of any great use.

In 1777 the Swedish chemist Scheele experimented with the action of sunlight on chemically treated glass, and about 1798 we find that a man by the name of Senebier and a certain Count Rumford discovered some important



Eastman Kodak Co.

AN EARLY PHOTOGRAPHER'S EQUIPMENT

light-sensitive chemicals and the elements of which they were composed. From this time on, slow steady progress was made. In 1801 Ritter isolated the violet ray, and the next year Thomas Wedgewood, whose father was famous for his pottery, was successful in producing photographs with the use of silver chloride. Unfortunately he was unable to "fix" them properly, for the moment they were exposed to light they blackened and the image was lost.

THE FIRST PERMANENT PHOTOGRAPH

Undaunted by the difficulties which attended this experimental work, a Frenchman named Niepce continued, and after several years of research finally succeeded in making a permanent photograph, giving his plate an exposure of eight hours. Just think of it! It took eight hours to accomplish that which to-day takes but a fraction of a second, for now the camera is so marvelously made that it is possible to photograph a rifle bullet in flight. Niepce had made photography an assured fact, it is true, but the Royal Society of England refused to recognize him since he would not divulge his process.

During all this time Louis J. Daguerre in France was busily engaged on the same problem, and after Niepce returned from England the two kept in touch with each other. In 1839 Daguerre perfected the process which was named after him and which we call the "daguerreotype." This was in effect a photograph made on silver-plated copper. Many daguerreotypes are in existence to this day, almost a hundred years old yet clear and distinct. Daguerre, besides producing a permanent photograph, also cut down considerably the time needed for exposure.

In the same year Fox Talbot discovered the "salt print" process, and efforts were being made to print photographically. The introduction of collodion in 1850 helped materially.

REPRODUCTION OF A "TINTYPE" OR FERROTYPE

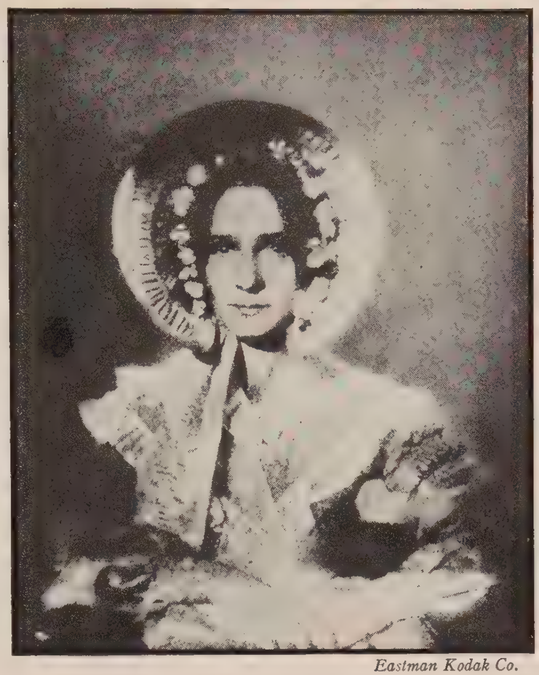
DEVELOPING A SENSITIVE EMULSION

In the meantime experimenters in America were not idle, and the year 1840 saw the first portrait ever made in this country. Professor John W. Draper posed his sister Catherine before a camera, and for ten exhausting minutes she sat in the brilliant sunshine scarce daring to breathe, but at the end a ten-minute exposure had become a reality. Contrast this to the eight-hour exposure of only a few years earlier.

Science and industry, alert to the significance of the daguerreotype, turned their attention toward the development of more sensitive photographic emulsions, for slowness was a continual hindrance. The result was the present-day panchromatic film. The new emulsion used special dyes to increase sensitiveness to red, yellow, and green rays, and was indeed a tremendous step forward because prior to this time only blue and violet rays registered satisfactorily. To-day panchromatic films and plates are indispensable in rendering accurately all color values as seen by the eye. A super-speed panchromatic emulsion recently placed on the market has made possible the making of photographs in darkened interiors such as theaters, utilizing the illumination of the ordinary electric-light bulbs to be found there. Another type, sensitive to infra-red rays, has made aerial photographs of mountains more than two hundred miles distant from the camera and invisible to the eye.

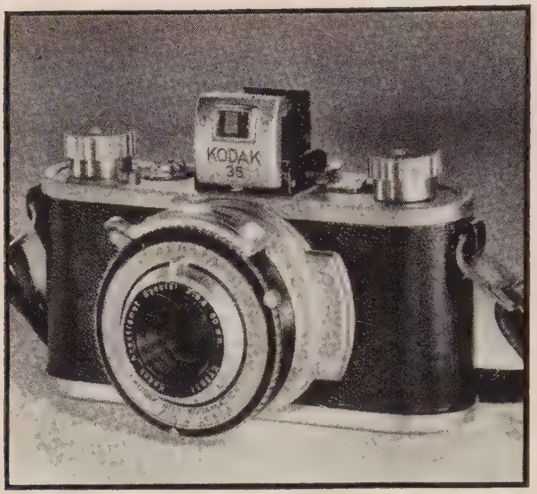
CAMERAS AND LENSES

During the time that the film and plate were in a process of evolution, the camera, too, was keeping step. The first "camera obscura" which Wedgewood used was followed by an improvement in the lens by Porta. His lens was what is called a "plano-convex," the convex side being turned toward the ground glass. Daguerre, on the other hand, secured his cameras from Chevalier, a French optician, who made them with the convex face of the lens away from the ground glass. Then Andrew Ross, in England, made another improvement by changing the flat surface of the lens to concave, and combinations of lenses used together soon followed. "Wide-angle" lenses to take in more space than the ordinary lens could encompass were next produced, and of late years a lens often referred to as a "soft focus" or "diffused focus" lens has become very popular, especially in feminine portraiture. This particular lens deals in a kindly manner with those upon whose faces Time is etching the tiny tell-tale lines that denote the passage of years. So well does the lens diffuse and soften the light that the finished portrait reveals a satin-like smoothness of skin that flatters immensely.


Eastman Kodak Co.

AMERICA'S FIRST CAMERA PORTRAIT

The various processes by which we produce the present-day portrait have been greatly simplified since Daguerre's time, but the fundamental basis of silver-coated paper, exposed to light and then fixed with hyposulphite of soda still remains. One change which was helpful applied a coating of albumen to the surface of the paper as a base for the depositing of silver. This resulted in a distinct and much more brilliant image. Year by year, one improvement has followed another until it is indeed a far cry from the first camera, consisting of a black box with the light entering through a pinhole, to the beautifully finished instrument we now use.



A MINIATURE CAMERA

These very popular small cameras use film only 35 millimeters wide, the same size as that used in motion picture cameras. The prints are enlarged to any desired album size. Nearly all color transparencies are taken with these small cameras

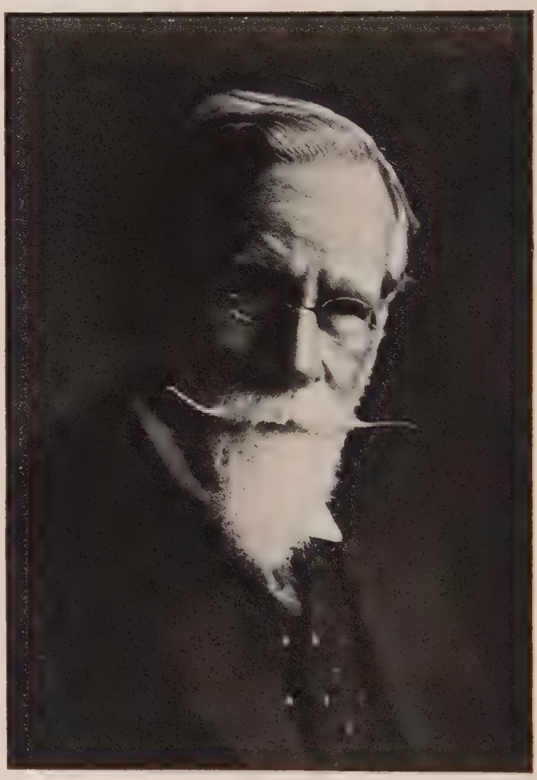
It is hard to hazard a guess as to just what would most interest any of our pioneers in photography if they were permitted to step into a modern studio, but it is safe to say that the use of artificial light would provoke considerable comment. Even the photographer of the early 1900's was by necessity forced to locate his studio on the top floor of some tall building, away up under the roof so that he might have huge skylights to let in the clear northern light he needed for indoor portraits. It was usually hot there in summer, and always, without exception, mighty cold in the winter. Today the studio is located wherever convenient and electricity supplies the illumination.

COLOR PHOTOGRAPHY

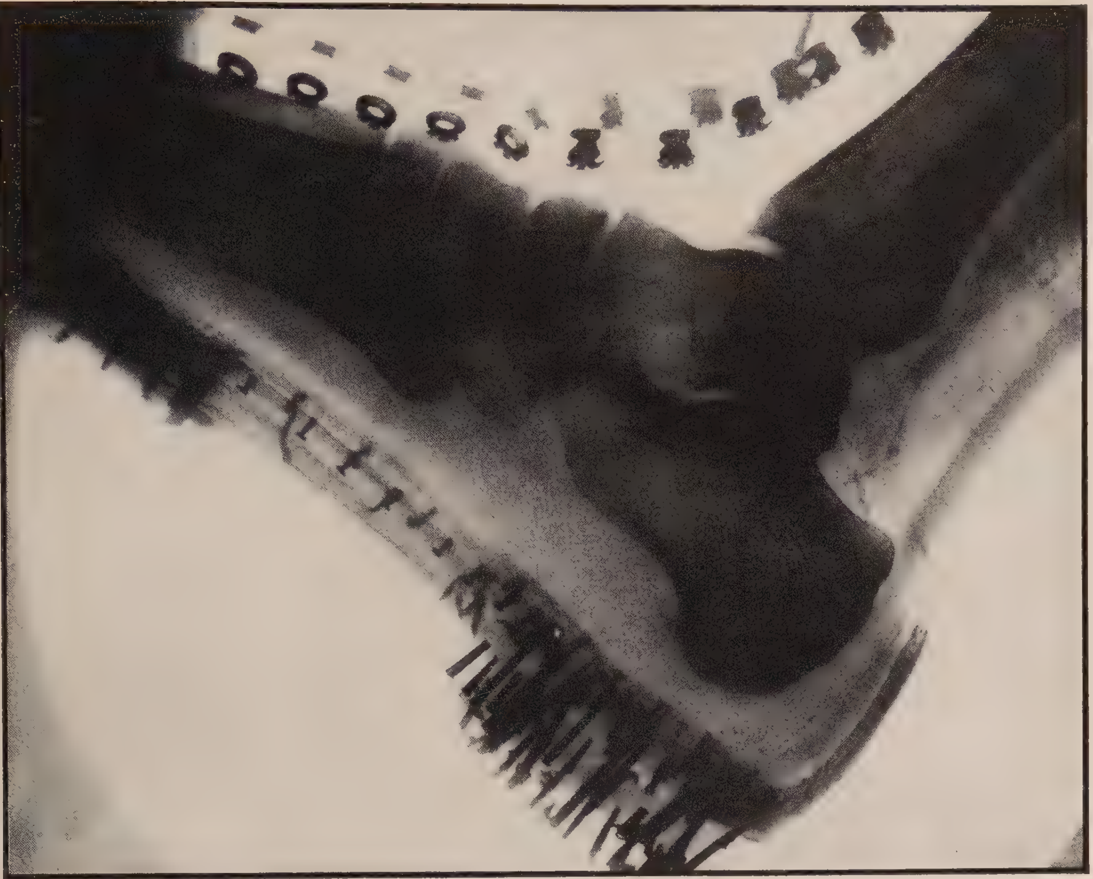
Photography in natural color, long the dream of camera enthusiasts and the subject of years of research by inventors and scientists, is now an accomplished fact. There are two general types of color photography. The first to become practical was the color transparency. Color film was devised which produced transparent positives in very life-like colors. These, however, will not produce a color print on paper—or, rather, they will do so only through a complicated and expensive process. The common way of viewing them is to place them in a projector as slides and throw the picture on a screen.

In 1941 a different type of color film was brought out. This film results in a direct color negative and permits the making of reasonably-priced color prints on paper. This is a great step forward, for it is much more convenient to have a color print on paper than to be obliged to set up a projector and screen whenever you wish to view a color picture. Color film and color prints are more expensive than black-and-white but the beautiful results obtainable make them well worth the extra cost. This is especially true for pictures of flowers and gardens or any picture where color is an important part of the beauty of the scene.

(The story of motion picture photography follows as a separate article beginning on page 151 of this volume. See also "Amateur Photography" in Volume Six, pages 236–244, and "The Nature Lover's Camera" in Volume Three, pages 369–372.)



SIR WILLIAM CROOKES
Pioneer in the field of radioactivity



REVELATIONS OF THE X-RAYS

In this case, by means of the X-rays, the source of a severe pain felt by the subject when walking was shown to be an abnormal growth, or spur, on the heel bone.

PHOTOGRAPHING THE INVISIBLE

SOME of the most highly important and practical discoveries of modern times have been made by men who were merely in search of additional scientific truths.

When Sir William Crookes, for example, first began his laborious experiments upon the effect of the discharge of an electric current through rarefied gases, no one would have imagined that his labors would lead to results of practical value. Yet to these painstaking investigations we owe the discovery by Röntgen of the X-rays, with their everyday application in medicine, surgery, dentistry, and industry, and their wonderful value in the location, analysis, and cure of disease and the saving of human life.

It was quite by accident that Professor Röntgen of the University of Wurzburg discovered the X-rays. He was performing some experiments involving the discharge of electricity through glass bulbs from which all but a trace of air had been exhausted. When the new radiation appeared, it seemed to differ from light and all other radiations. That was the reason why Professor Röntgen applied the name "X-rays," X being meant to stand, of course, for an unknown cause.

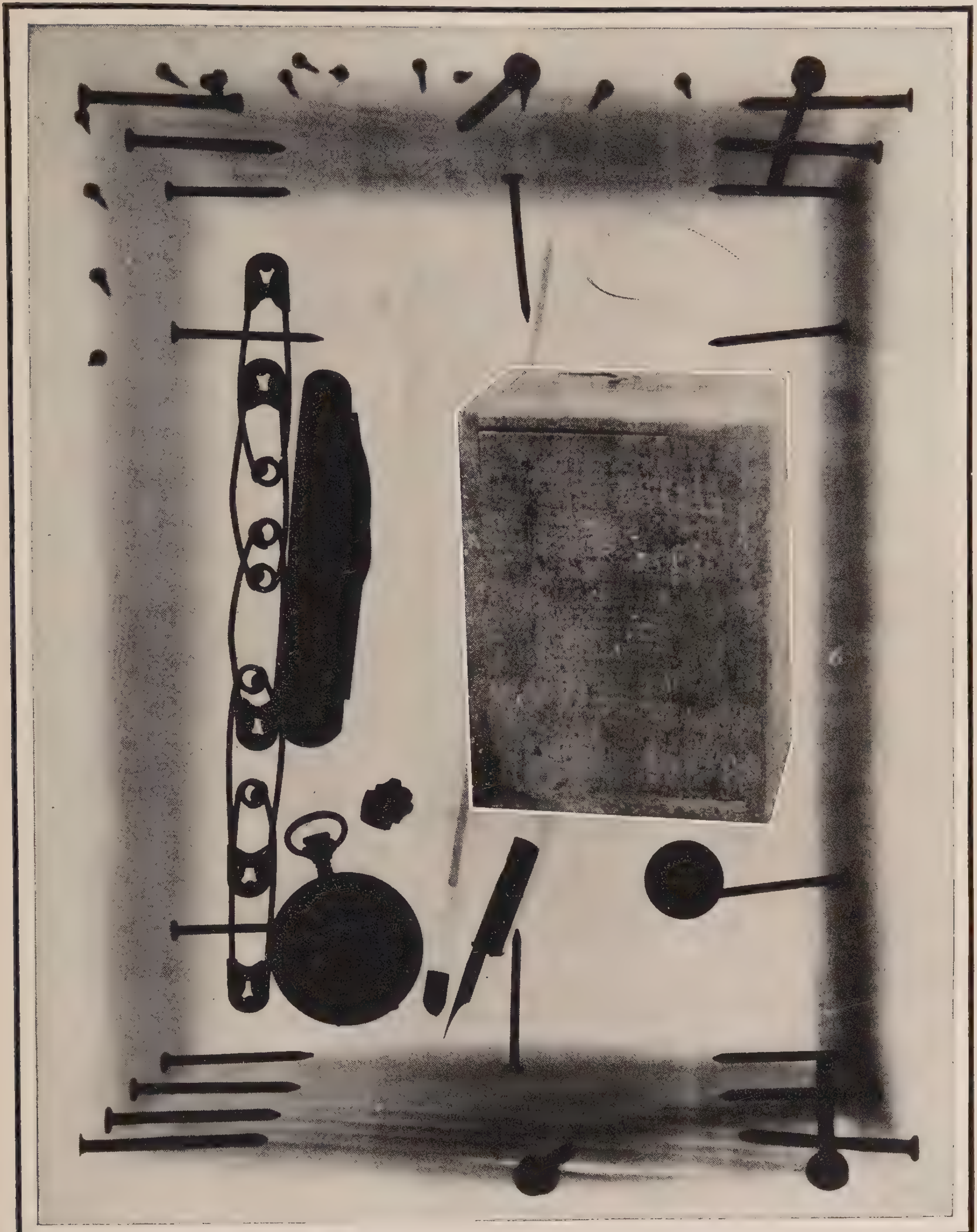
This discovery was made in 1895, and since that time the strange radiation, with its peculiar name, has been put to many practical uses. The most interesting feature of X-rays is the fact that they readily pass through substances which are entirely opaque to light, but are retained by materials through which light passes most freely. Glass, for example, which is always spoken of as transparent, absorbs the X-rays, but the rays are transmitted without difficulty through wood, aluminum, and human flesh. Great interest was manifested in the X-rays from the first, because of the fact that by means of them it was found possible to see coins in a locked box, the interior structure of a fish, and even the bones in a human body, the shadowy outlines being perfectly plain.

After a time it was found possible to combine photography with the X-rays, and then progress in the practical application of the rays became rapid. X-ray photographs are really shadowgraphs. If a human hand be pictured, very dark patches show the position of the bones, lighter patches show the muscles clinging to the framework of bones, and still lighter areas indicate the more transparent flesh. It is easy to understand that if a bone in the hand photographed is broken or if any abnormal condition exists, the shadow picture reveals the fact at a glance. For this reason X-ray photographs are extensively used by physicians and surgeons. Sometimes they are submitted to a jury as a very convincing form of evidence.

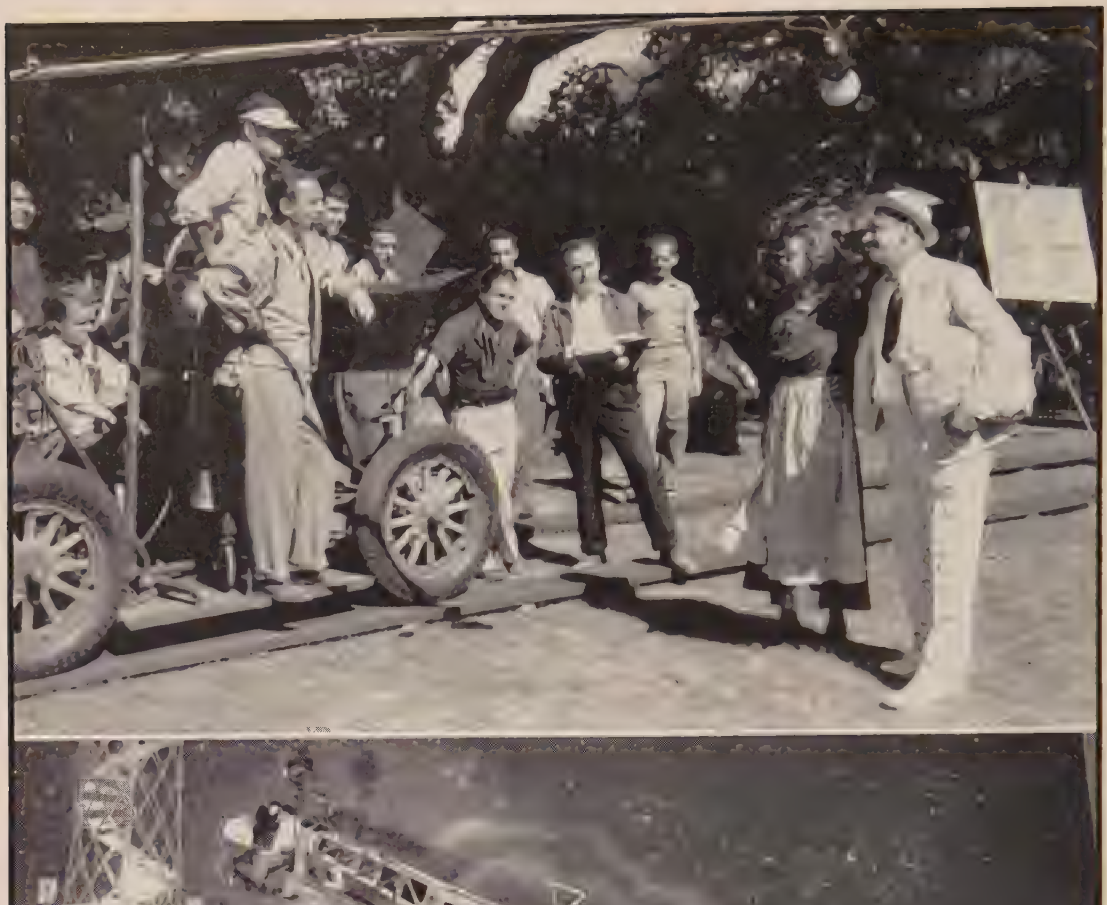
X-rays affect a sensitized photographic plate in precisely the same manner as ordinary light rays. These rays also have a very peculiar property. They are able to excite the fluorescent action of other substances, many of which are now known, so that they, too, will emit light. Certain of these substances are now commonly used in the making of special screens — often called "fluorescent" screens — on which the shadow pictures are cast when particularly accurate and clear images are required. When X-ray examinations are made directly, the room must be dark, and the operator usually prepares himself by remaining in darkness for ten minutes or more or by wearing dark glasses for some time, in order to protect his eyes. While the images are plain to any eyes, only an expert is qualified to report accurately on what is seen either on a screen or on an X-ray photograph. One must be perfectly familiar with radiographs of a normal structure before one can deal intelligently with those that are abnormal. Also, the X-rays must be used with a degree of caution. Many severe burns from these rays have been reported.

When X-ray pictures are made, an electrically lighted tube of special construction is used and the object to be photographed is placed between this tube and a sensitized plate. The plate is developed and printed from in the usual way. It may sound a bit startling, but it is a fact that in this manner a picture of a human skeleton may be obtained while its owner is yet alive. Using an X-ray machine in a darkened room, the action of the heart and lungs is plainly seen. The movements of the joints are made visible by the rays from the tube, glowing in green phosphorescence, while the spinal column and the ribs stand out boldly on the screen. Of course, the movements can be seen only by one on the spot, but the substitution of a plate for the screen gives a permanent record of all else that is seen. Sometimes the picture is made in daylight, which is quite possible if the plate is inclosed in some material which will protect it from the sun's rays. The X-rays will soon penetrate any covering of this sort. Formerly it was necessary to make an exposure of several minutes to get a negative by means of X-radiography, but so many improvements in the tubes have been made that now a few seconds often suffice.

When a radiograph of a man or woman is to be made, for a physician's use, all metal, such as buttons and buckles, and all articles of glass or bone are first removed from the subject's clothing. Plaster of Paris, adhesive plaster, and wood splints also interfere with the success of the work. Usually two views, say of a fracture, are taken from different angles, in order to secure an accurate record. X-ray pictures are often made use of in life-insurance examinations, and are employed for reference in hospital cases. By means of them the progress of a case may be shown and the study of difficult surgical problems greatly facilitated. It is probable that many possibilities in the use of X-ray photography remain to be developed.



THE CONTENTS AND STRUCTURE OF A BOX AS SHOWN BY THE X-RAYS



Photos, Metro-Goldwyn-Mayer

MAKING MOTION PICTURES

Top: On Location. Bottom: In the studio. In the lower scene the cameramen are swung aloft by a large movable boom thus enabling them to get a variety of interesting angles for their "shots."

MOTION PICTURES

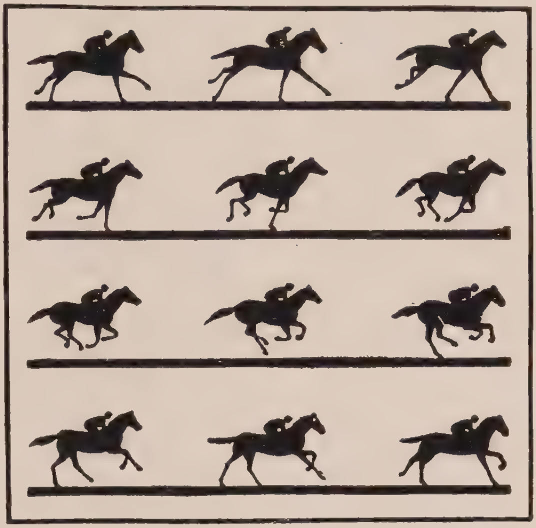
So many wonders are worked by photography that we are stirred by a new one only when it is very wonderful. The motion picture has within a few years astounded and delighted the civilized world. That the people in a picture should move as freely and as rapidly as in real life is sufficiently surprising, but the miracles of modern science now show us these people in their natural colors and make them talk to us as well. By the motion picture we are enabled to see strange and beautiful sights from all parts of the world. Its films preserve for us a visible record of exploration, history, and indeed of all the phases of human activity. In addition to being one of our most important methods of entertainment, it has become a tremendous educational force as well.

THEIR INVENTORS

Without the sensitive film, the motion picture would probably never have become practical. The celluloid film, invented in 1885 by the Rev. Hannibal Goodwin, was clear, light, transparent, and flexible, and proved to be the perfect material. While early film was so inflammable as to be almost explosive, later developments have made it non-explosive and in some types non-inflammable.

It is easy to see how accurate must be the machine that is to show pictures on a screen at the rate of a thousand a minute. As early as 1883 a device had been made for showing a sort of motion picture, not on a screen, but as a series of rapidly moving pictures passing by a slit, which gave the effect of continuous motion. Other inventors made important contributions. Thomas A. Edison, gathering the threads left by others, turned to the problem in 1888 and patented his kinetoscope in 1893.

A HORSE RACE AS PICTURED BY THE ARTIST

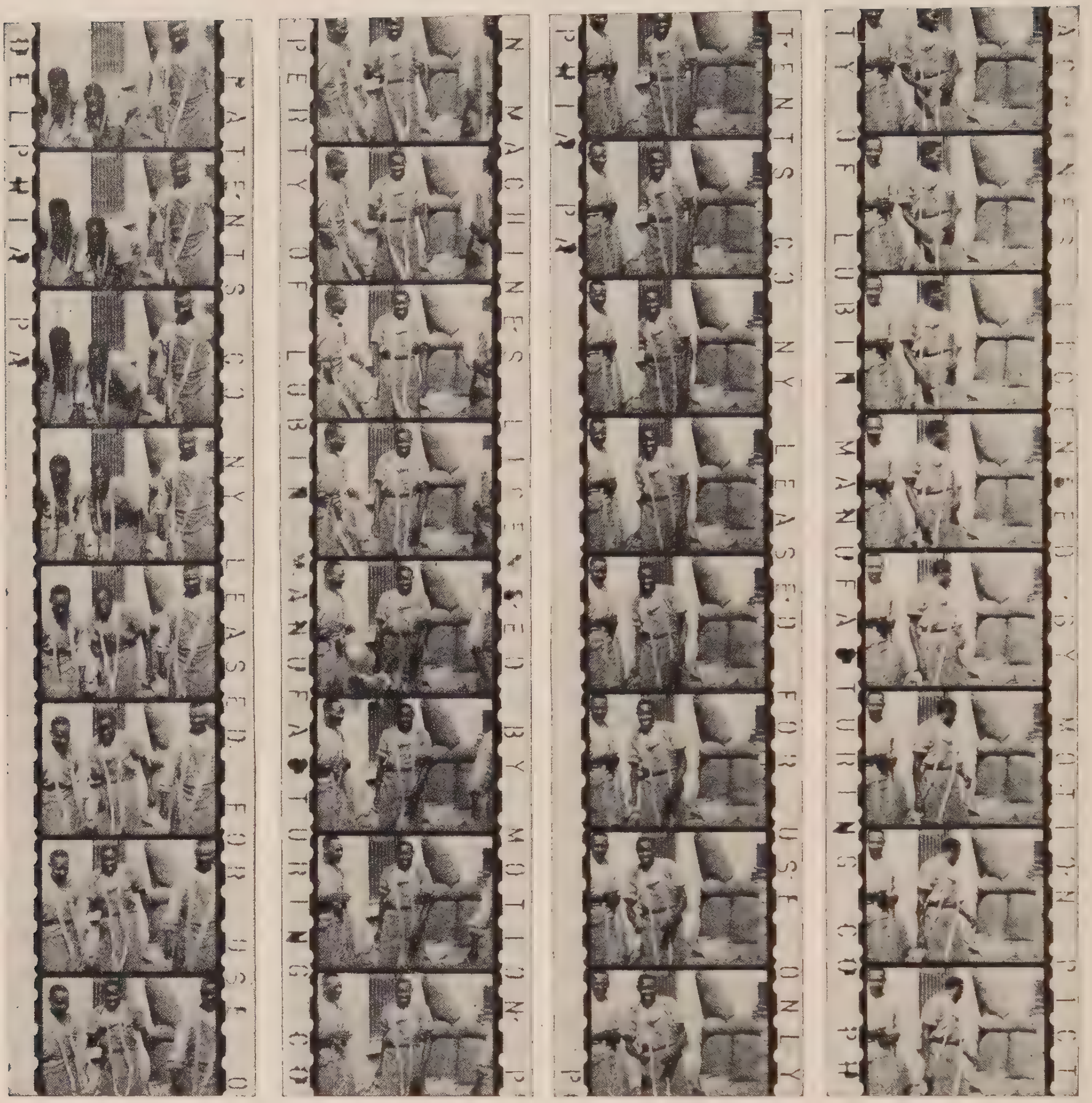


ACTUAL POSITIONS TAKEN BY A RUNNING HORSE

This was the first smoothly working apparatus and produced sharp, clear images. The kinetoscope's pictures, however, could be seen by only one observer at a time, and it was not adapted for showing on a theater screen. Credit for producing "the first successful form of projecting machine for the production of life-size pictures from a narrow strip of film" has finally been awarded to C. Francis Jenkins, of Washington, D. C., who has received more recent attention for his pioneering in the field of television.

In 1872, Edward Muybridge, of Oakland, California, became interested in a study of the motions of running horses. He made twenty-four successive pictures of a horse in rapid motion by means of a series of cameras placed at intervals along a race track. These pictures, placed in a pile and riffled over so that each would be seen successively, seemed to show the horse in motion. Muybridge may well be called the father of motion-picture photography.

Although so-called motion pictures had been exhibited previously, the motion picture as we know it was not shown until 1891 when



Courtesy of Lubin Mfg. Co.

PORTION OF A MOTION-PICTURE FILM

Showing its exact width, and the minute changes in each successive view.

Jenkins exhibited his "phantascope" to friends. The first public showing of this machine was in 1894, when a strip of film picturing a dancing act was exhibited in Richmond, Indiana.

HOW THEY ARE MADE

It all comes about because the image of an object which light makes on the retina of the eye lingers there a moment after the cause of it has passed on. The celluloid film made the moving picture possible. This, coated with the sensitized silver emulsion, is as transparent as glass after development, yet is supple enough to be bent and wound as if it were silk or paper. A very long film is wound through a camera in such fashion that a single picture is taken while the film rests; then it moves on and another picture is taken, and another, until sixteen have been taken in a single second. Each picture records a very slight change in the motion of the objects it depicts. When the negative film is developed and dried, it is used to print a positive film, just like a lantern slide, and this positive is put into a projector so that it passes through the space in front of a lens in the same way that it went through the camera. Thus each picture is thrown for a fraction of a second, motionless, on the screen, then is quickly snatched away and the next substituted, and so on until all the reel is used up.

But because of the slowness of the eye to give up an image formed on the retina, each picture stays until the image of the next one has begun to form there and the changes of position in the picture move on exactly as in real life. It is all very simple, but it is all wonderful, and the accuracy and cleverness of the mechanism which handles the film should come in for a fair portion of our wonder and admiration.

In addition to its part in recording the scenes of nature, the motion picture has become the field for the employment of armies of actors and attendants in producing plays, the staging of which often cost hundreds of thousands of dollars. The subjects are not only such scenes as may be produced in a theater with all its tricks of scenery and lighting, but great troupes of actors are taken to remote places where natural surroundings are such as will best make the matter realistic.

MOVING PICTURES IN COLOR

But now we come to the even more interesting question of how moving pictures are produced in all the variety of natural colors. The "three-color process" by which colored pictures in the magazines are commonly printed makes use of three plates — one to print all the red there is in the picture, another to print all the yellow, and the third to print all the blue. When all three have been printed, one on top of the other, the "piled up" colors give us a fairly accurate color print.

It was natural that an attempt should be made to employ this principle in the making of colored *moving* pictures. At first, three distinct films were used, one for each of the three primary colors — red, yellow, and blue — but it was found impossible to maintain the exceedingly delicate adjustments necessary to keep the three films operating in perfect unison.

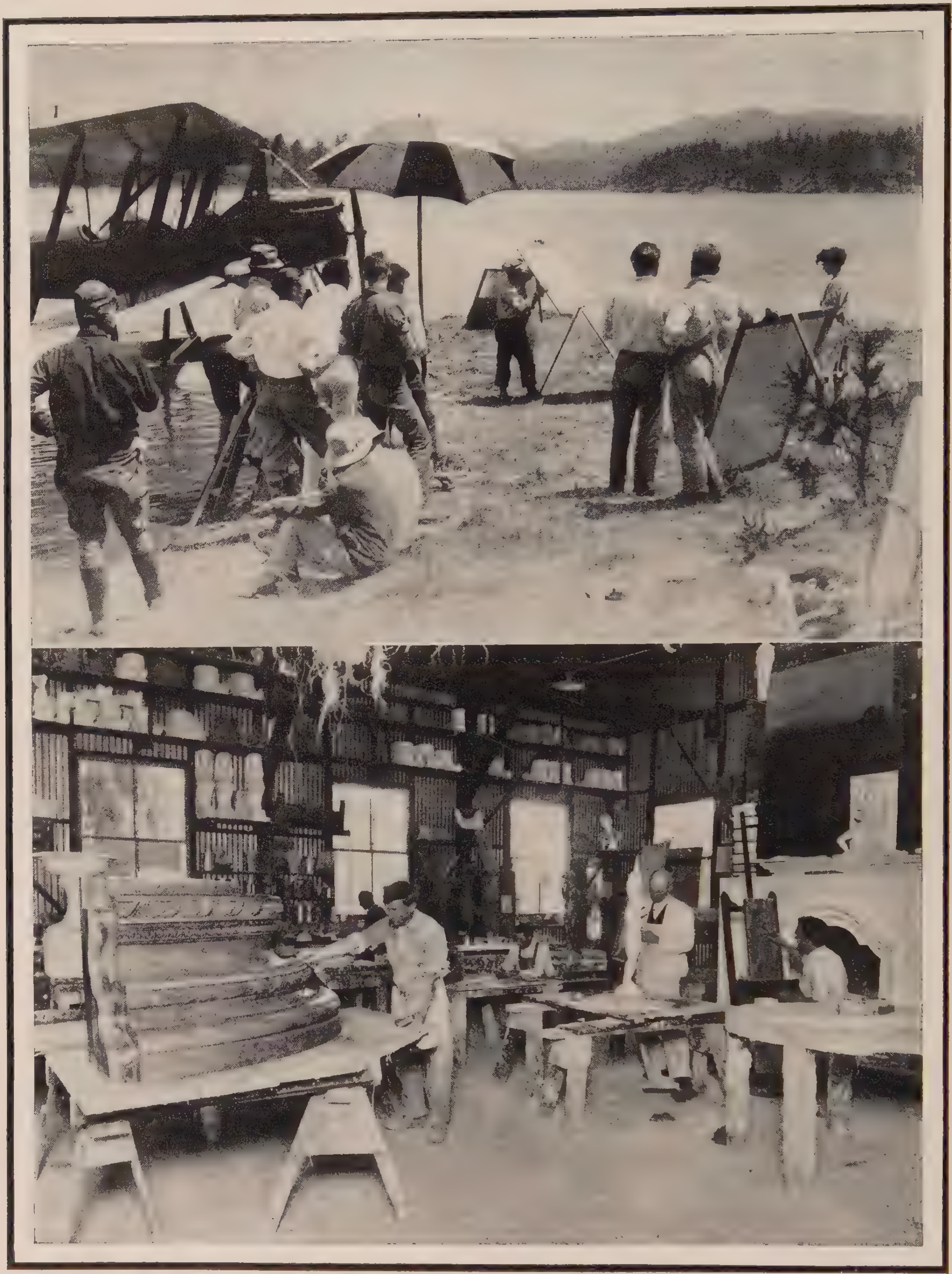
A further step forward was the "Kinemacolor process." This made use of the principle of "persistence of vision," which is that the image made by any picture on the retina of the eye, as explained above, remains there for a moment after the picture itself has been withdrawn. Thus if the proper red picture were quickly followed by the proper blue picture, and this in turn were immediately followed by the yellow picture, the colors would be "piled up" on the retina of the eye, and the eye itself would make the necessary combination of the colors.

When the picture was being taken, a rapidly revolving disc brought before the camera lens first a red screen and then a green screen (the latter being used in place of a blue screen and a yellow screen), so that the film when finished was made up of individual pictures alternately prepared, one for the red light and one for the green light. By using the same sort of revolving disc when the pictures were being thrown on the screen, the pictures were alternately red and green, but the eye very kindly composed the pictures into one, in which the colors appeared almost as in Nature.

THE TECHNICOLOR PROCESS

Most of the color films which you see to-day are made by a newer method, developed after years of experimentation by Professors Kalmus and Comstock of the Massachusetts Institute of Technology. The earliest process, brought out commercially in 1928, was a two color method, utilizing red and green From your reading in Volume One you will remember how the sun's light can be split up by a prism into the various colors of the spectrum. In taking the pictures a special camera was used, which employed a prism to split the incoming light rays into their red and green components.

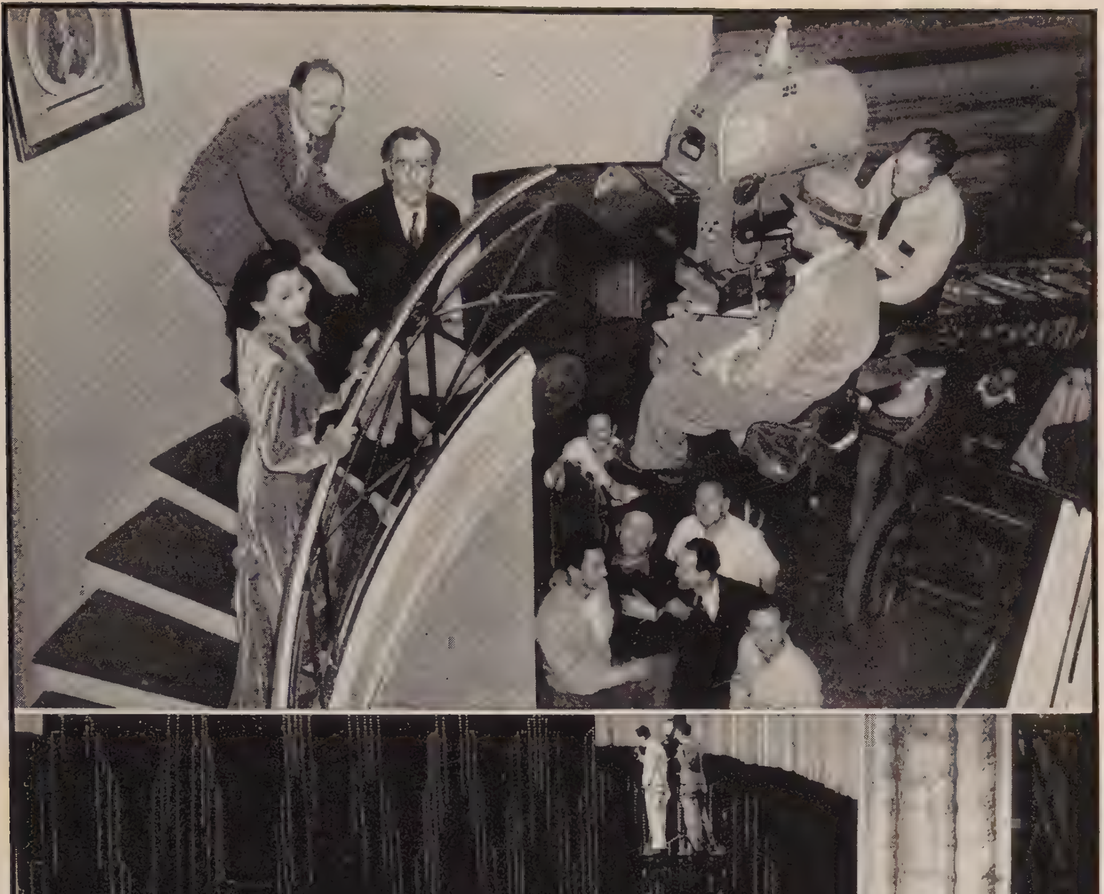
Today, however, a three color process is employed. The camera splits the light into red, blue and yellow components, photographing each on a separate strip of film. When the films are developed, the images on them are seen in black and white. In the next step, three prints are made from these negatives,



Photos, Paramount Pictures

MAKING MOTION PICTURES

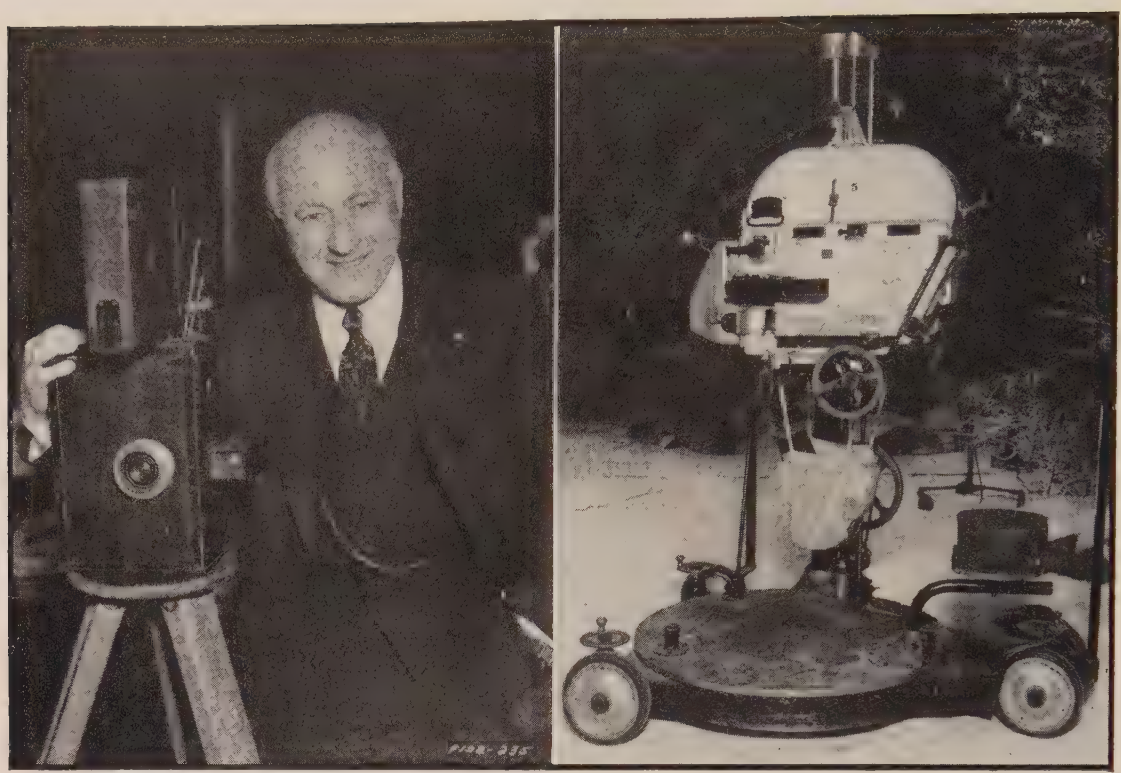
Top: Outdoor scene, with airplane. Note the use of reflecting screens for photographing the girl at the right. Bottom: Making models for scenery.



Photos, Metro-Goldwyn-Mayer

MAKING MOTION PICTURES

Top: Camera follows the players upstairs by use of movable crane. Bottom: Shooting a song-and-dance act in a musical production.



LEFT: CECIL B. DE MILLE, PIONEER PRODUCER, AND HIS FIRST CAMERA. RIGHT: A MODERN CAMERA

using a special printing device which transfers the red images to one film, the blue to another, the yellow to the third. These prints are developed in a special solution which brings out the images in relief instead of the flat images of ordinary black and white film.

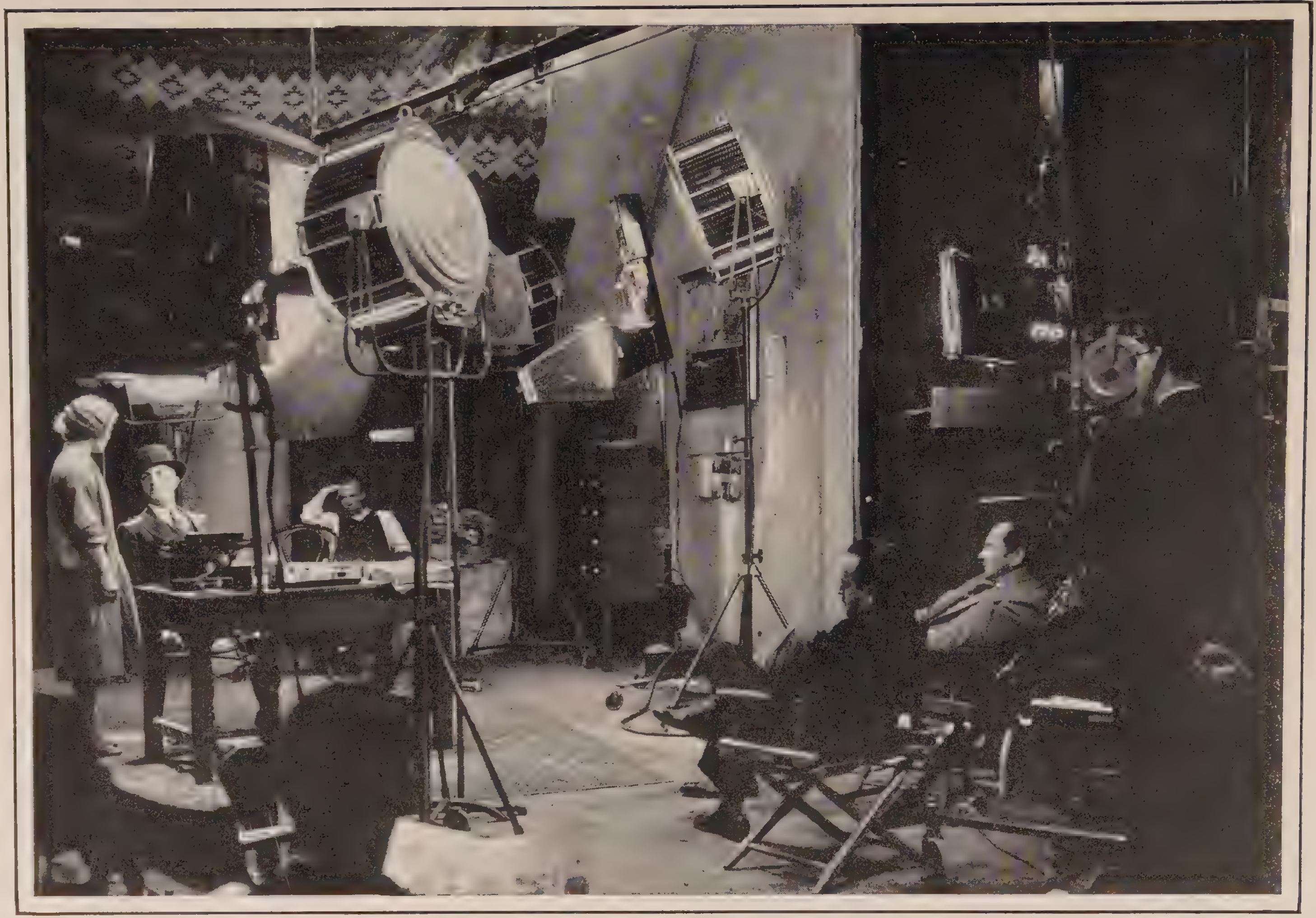
The films, known as "matrix" strips, are placed in an automatic machine which impregnates one with red, one with yellow, and one with blue dye. When impressed on a celluloid film each matrix deposits its dye. Thus in turn the red, yellow and blue images are transferred to the blank film, forming the finished film which can be used in an ordinary projection machine.

For the amateur taker of moving pictures another type of color film has been developed in which chemicals in the emulsion are sensitive to different colors. The film is used in an ordinary movie camera without prisms, and when specially processed becomes a finished color film. However, no duplicate copies can be made and this fact limits its use to the amateur only.

HOW SOUND IS RECORDED

While we tell you of sound pictures under "The Miracle of Light," it is difficult to place them exactly under that heading, as they make use not only of light, but of the principle of the vacuum tube amplifier which we use in radio.

The method used in motion pictures to record the dialogue and music is one which involves the actual photographing of sound. This seems like an impossible procedure, yet it is really very simple. As you have seen in an earlier chapter, the strength of an electric current can be varied by the action of sound waves. In recording sound, a narrow beam of light is focused on the edge of the motion-picture film. The strength of the beam is controlled by a "light valve," an electrical device that changes the brilliance of the light in exact proportion to the variance of sounds which strike it. Sounds will thus appear as a succession of light and dark lines along the edge of the photographic film.

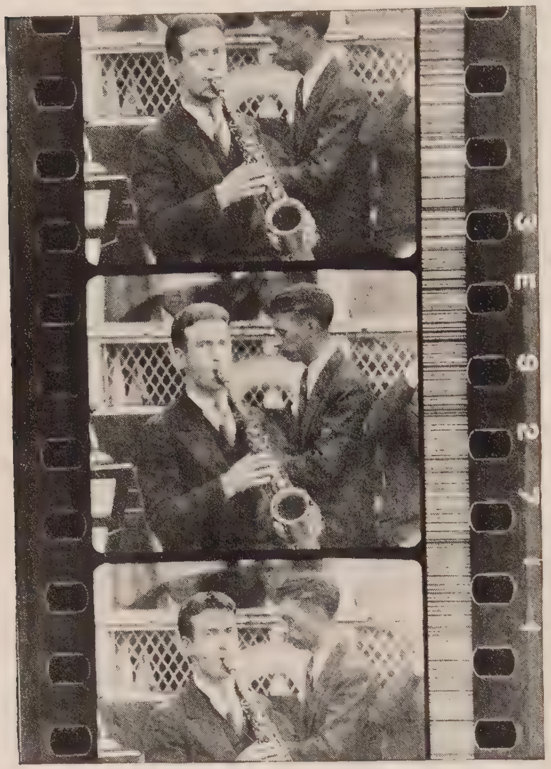


Paramount Pictures

MAKING A TALKING PICTURE

To the right are directors and cameras; to the left the actors, facing a battery of powerful lights. The microphone hangs from the tube-like arm seen at the top of the picture.

In reproducing the sound in the theater the opposite process takes place. A beam of light, passing through the film record, falls upon a photoelectric cell which allows a varying electrical current to pass through a series of vacuum tubes, turning the light back again into sound. This is amplified and sent out over loud speakers as mentioned above.



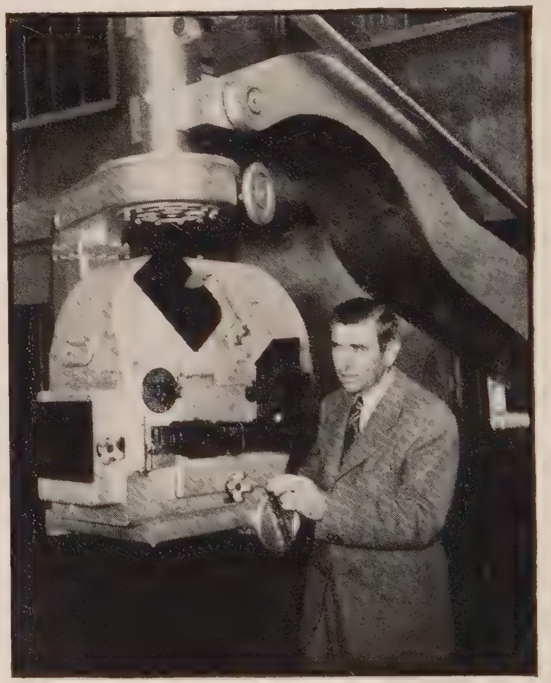
Western Electric Co.

A SECTION OF SOUND FILM

The shaded lines at the right are the photographic record of sound.

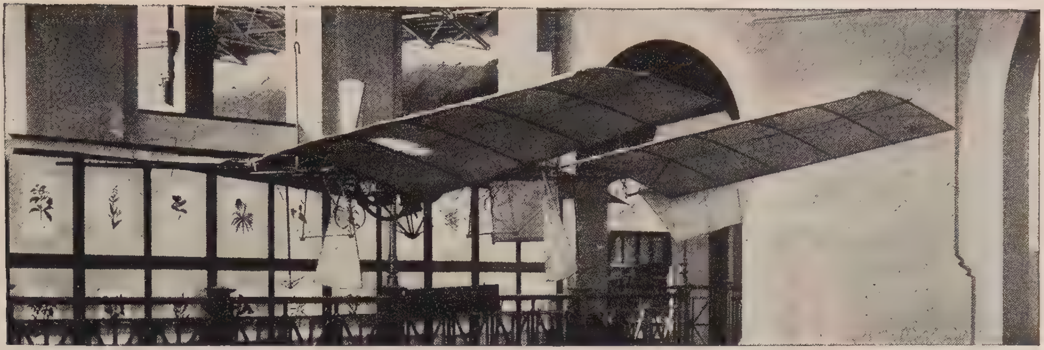
The taking of sound pictures has introduced many new problems in studio operation. "Sets" which were formerly hastily thrown together must now be carefully made on stages soundproofed against the intrusion of external noises. The microphones are so tremendously sensitive that an accidental cough or sneeze may make it necessary to re-take an important scene. Even the rustling of paper is magnified by the apparatus until it sounds like the crackling of machine-gun fire, so that special noise-proof paper has had to be developed. Cameras are in sound-proof cases, called bungalows, photographing the scenes through windows of clear plate glass. Naturally, dialogue must be carefully learned and the action thoroughly rehearsed before cameras and microphones can be put into operation, as the making of these pictures is much more complicated and expensive than in earlier days when pictures did not "talk."

It is interesting to think, when watching talking pictures, how science has so successfully combined light and electricity to give us this marvelous form of entertainment. Sir John Herschel, who discovered "hypo," the chemical by which photographs are "fixed," said in 1860 that "the representation of scenes in action by photography" was a realizable dream. That early prophecy has been brought to fulfillment through years of painstaking effort. The present motion picture is not an invention, but a combination of hundreds of inventions and scientific discoveries. It may well be taken as an example to show how the problems of our complex civilization can be solved only through mutual helpfulness and co-operation.



Metro-Goldwyn-Mayer

CAMERA IN SOUND-PROOF "BUNGALOW"



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A MODEL OF THE LANGLEY AËRODROME

THE INVENTOR AND THE SCIENTIST

INVENTION follows hard upon the heels of knowledge — indeed, sometimes leads the way. Practical use of electricity, for example, far outstrips scientific knowledge of that marvelous force, although the scientists are beginning to catch up with the inventors in this field. Of course electricity was known before the inventors found its manifold uses; but it was that use which the inventors made that led to the real knowledge of electricity. Faraday and Franklin precede Morse and Edison; but these, in turn, precede Clerk-Maxwell. And this is the history of the relation between science and invention in all lines. Laboratory experiments by a few scientists with more imagination than their fellows; or better luck, throw out a hint as to some new force or new applications of well-known laws. The inventor is sure to seize on the hint. A practical development of the newly discovered force is worked out. This development leads the way to new knowledge and sets the whole world of science to thinking.

THE INVENTOR'S USE OF HIGH TEMPERATURES

Here again the inventor turns scientist, or the scientist turns inventor, if you prefer to put it that way. The action of materials under the influence of very high temperatures differs not only in degree but also in nature from their action under ordinary temperatures. Some of these differences are used by inventors and have already revolutionized the practical way of doing many simple things. The whole subject is another of those which lie on the borderland of the unknown, and which open up possibilities of which we dare not prophesy — not for fear that we shall be extravagant, but for fear that we shall limit the truth.

CUTTING STEEL BY HEAT

A French inventor, Le Chetalier by name, taught the world the use of the high temperature produced by a flame of burning acetylene gas and oxygen. He invented a torch for burning this mixture of gases and directing the heat to a sharply focused point. Now it seems to be one of the peculiarities of very high temperature that it does not spread in the same manner as low temperature. By directing this thin, intensely hot flame against a plate of steel, the heat cuts its way through the metal in a sharp line, and the metal on each side of the cut remains uninjured. If you watch anyone using this torch, you will see, in a moment after the heat has been applied, a little shower of sparks appear from the opposite side of the plate. The flame has cut its way through. Now, if the workman passes the flame slowly along the line he wishes to cut, the plate will be severed as cleanly and perfectly in a few minutes as it could have been done with a saw in as many hours. More than this, the temper of the most finely tempered steel will remain uninjured. This is the most extraordinary fact of all. For if you were to put such a piece of tempered steel into an ordinary fire, you would soon destroy its temper. Indeed, care must be taken, even in sawing it, that the heat of friction is not too great, or the temper of it will be "drawn," as it is called. Here again we are face to face with new wonders of natural law.

The acetylene torch is also used for welding great shafts, and this can be done, often, without removing the broken part from the machine. In other words, what a few years ago would have been difficult and costly to repair can now be accomplished at comparatively slight expense and with great ease.

RADIUM

MEN of science themselves consider the discovery of radioactivity and of the element radium to be epoch-making to an unusual degree, for it was the forerunner of a series of investigations which are changing the whole theory of the structure of matter.

Sir William Crookes's investigations of the action of an electric current when passed through a glass tube containing various kinds of gases led to the discovery by Röntgen of the X-rays, so called because their exact nature was unknown. In his search for additional scientific truths, M. Henri Becquerel endeavored to find out whether other phosphorescent bodies beside the glowing X-ray tubes could produce penetrating rays. There is a somewhat rare element, called "uranium," which possesses a phosphorescent action, and M. Becquerel decided to investigate its properties. He wrapped a photographic plate in black paper and placed on it a bit of copper in the form of a cross, covering the metal with some uranium salt. When the plate was developed a few hours later, the image of the cross was found upon the negative.

This result started a search for an element capable of emitting still more powerful rays, and after much labor Professor Pierre Curie and his wife, Mme. Sklodowska Curie, discovered that pitchblende has a radioactivity four times as powerful as that of uranium. This fact convinced them that the radioactivity of the uranium salts was not due to uranium itself, but to some other element. After a long series of investigations and almost endless chemical processes, the Curies at last succeeded in isolating a radioactive salt that was found to have no less than 1,800,000 times the activity of Becquerel's sample of uranium. This radioactive salt was chloride of radium. How long and how hard a task was theirs can be understood from the fact that from their original single ton of pitchblende ore they finally obtained only the hundredth of a gram — one-seventh of a grain — of radium salt — the most precious and marvelous powder ever produced.

PROFESSOR PIERRE CURIE

"The wonder of this powder," says Professor E. Ray Lankester, "incessantly and without loss, under any and all conditions pouring forth by virtue of its own intrinsic property powerful rays capable of penetrating opaque bodies and of exciting phosphorescence and acting on photographic plates, can perhaps be realized when we reflect that it is as marvelous as though we should dig up a stone which, without external influence or change, continually poured forth light or heat, manufacturing both in itself, and not only continuing to do so without appreciable loss or change, but necessarily having always done so for countless ages while sunk beyond the ken of man in the bowels of the earth."

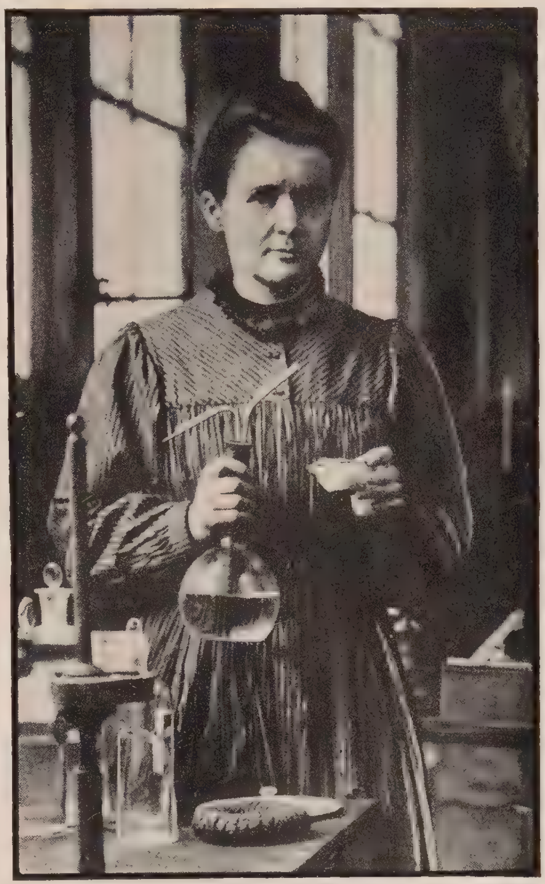
Radium gives out enough heat to melt rather more than its own weight of ice every hour; enough heat in one hour to raise its own weight of water from the freezing point to the boiling point, and while it does lose some of its atoms in the process, the number is so small that after the passage of 1760 years only half of them will be destroyed. The particles which compose these lost atoms also break apart and go shooting out at tremendous speed. Heat is generated through their impact with other bodies. If the sun contains a fraction of one per cent of radium, the presence of the element will account for and make good the heat that is continually lost by it. And if only a small amount of radium is scattered through the surface of the earth, it will be enough to maintain the temperature of our globe against all loss by radiation.

RADIUM AND THE AGE OF THE EARTH

This fact alone has made it necessary to revise all the estimates as to the age of the earth. Up to this time geologists have believed that the surface of the earth has enjoyed the same temperature as at present for some thousand million years. The physicists, however, have estimated the age of the earth to be from ten to one hundred million years, basing their estimates upon the rate of cooling of a sphere of the size and composition of the earth. The discovery of radium proves that the earth's material is not self-cooling, but self-heating.

When radium and certain other radioactive substances are dissolved in water, they produce a peculiar emanation, or gas, which changes in a few days, in part, into helium, a light gas that exists in great quantities in the sun. As the presence of helium would indicate the previous presence of radium, this fact proves the existence of large amounts of radium in the sun, and would account for that body's apparently inexhaustible production of heat. Helium, too, has been found in most hot springs and in many radioactive minerals in the earth, so that we may conclude that the earth itself contains no small amount of the mysterious element.

Radium and other radioactive elements are peculiarly unstable; that is to say, their atoms are constantly giving off energy, or heat, at a tremendous rate, over one hundred thousand miles a second. How fast this is can be realized from the fact that a modern rifle bullet travels less than half a mile a second. Scientists are now convinced that these elements are not the only ones which possess this extraordinary and practically imperishable energy. They believe that the calcium in gypsum, the sodium in common salt, and many other elements have this tremendous force. As Sir William Ramsay has said, "If some form of catalyzer (or key) could be discovered which would increase their inconceivably slow rate of change, then it is not too much to say that the whole future of our race would be altered." Many men of science believe that this secret will some day be discovered and that men will eventually be able to tap these now unfamiliar stores of energy and apply them to the future needs of humanity.



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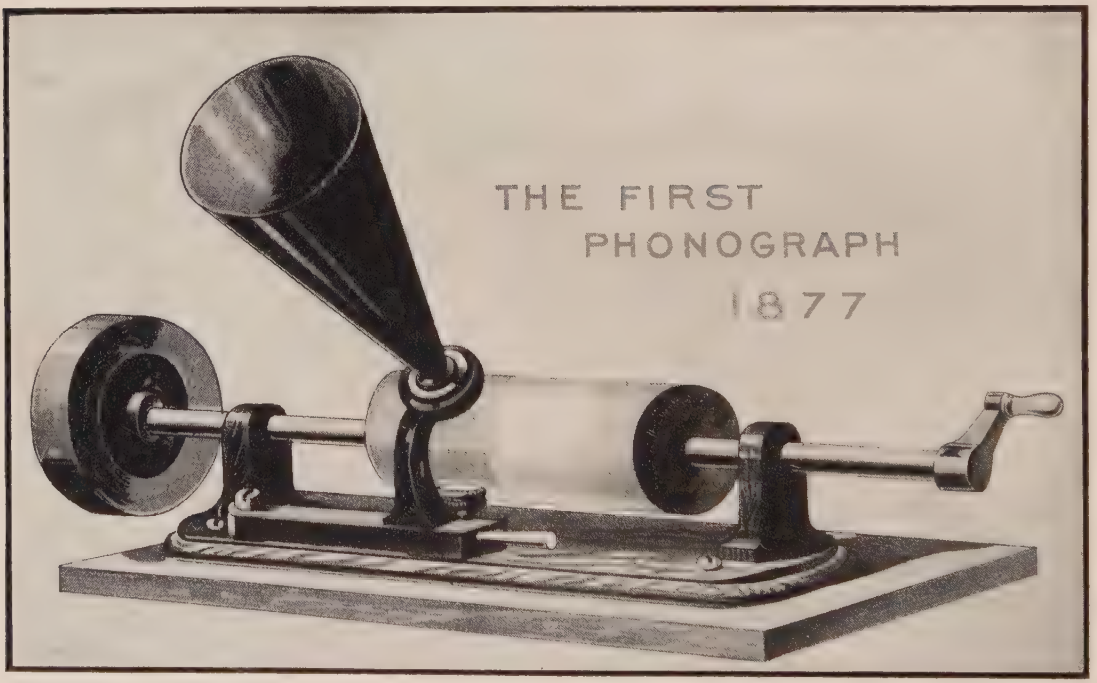
MME. CURIE IN HER LABORATORY

THE PHONOGRAPH

AMONG the many brilliant ideas which have sprung from the marvelous mind of the wizard Edison, few have produced a more lasting impression on the world at large than that which made the modern talking machine possible.

The first phonograph appeared in 1876, but as early as 1856 an instrument was devised by a man named Scott, which would mechanically register the atmospheric vibrations caused by the human voice or by musical instruments. This, however, was only a recorder, not a reproducer, and this second part did not make its appearance until Edison embodied both principles in his first phonograph. It was a very simple instrument and consisted of a metal cylinder finely threaded with a continuous square-section groove. This was mounted on a long spindle supported on upright bearings and having at one end a screw thread with the same pitch as that cut on the cylinder. A heavy flywheel was also placed on the spindle to make the speed of rotation uniform, and the whole was turned by a handle. A thin sheet of tin foil was stretched over the grooved cylinder and on it rested a steel point held down by a spring and separated from a vibrating diaphragm by a rubber pad. There was also a large mouthpiece to concentrate the sound vibrations.

To make a record with this machine a person would speak into the mouthpiece, turning the spindle by hand at the same time. The vibrations set up by the voice acted through the diaphragm on the steel needle and caused its movements to correspond with these voice vibrations. Then the needle, passing over the tin foil directly above the grooves in the cylinder, forced the thin sheet down into the grooves to a greater or less degree according to the vibrations. When the record was completed the needle could be again started in the grooves it had just made in the tin foil and the variation in the shape and depth of the grooves caused by the different vibrations of the voice would reproduce the sounds which had caused the vibrations. This first instrument, of course, had many faults. It was heavy, clumsy, and harsh-toned, and the records became quickly worn out.



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After getting out this machine, Edison did no work on the phonograph for some years, his time being occupied with the telephone and electric lamps. During this time, two brothers, Graham and Chichester Bell, and one Charles Taintor, developed and improved the ideas started by Edison. A thin wax coating on a paper cylinder was substituted for the tin foil, and the spindle was turned by a clock-spring-driven motor instead of by hand.

When Edison again turned his attention to the phonograph, he introduced an all-wax cylinder and invented a machine by means of which the surface of a worn record could be shaved off and a new record made on the fresh surface.

While at present the phonograph has its greatest use as an entertainer, yet its practical value is continually being demonstrated along many lines. It is used in offices for repeating dictation to a stenographer, as a teacher, particularly in instructing in the foreign languages, and in many other similar ways.

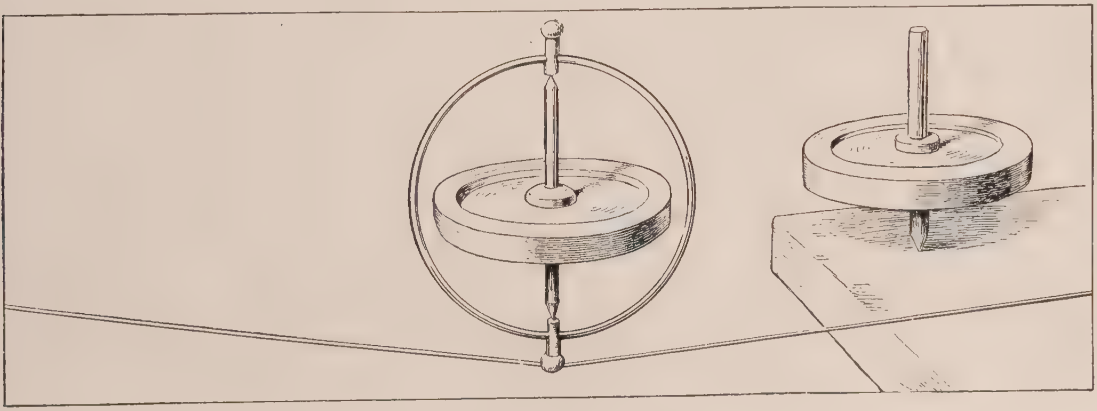
(The story of Thomas Alva Edison, inventor of the phonograph, is told on page 169.)

THE GYROSCOPE

THE gyroscope has long been one of the most marvelous of scientific toys, apparently disobeying all the laws of mechanics with which we are familiar. Until recently it has been little more than a toy, although many attempts have been made to apply it to practical uses. In the last few years, however, inventors have succeeded in overcoming many of the technical difficulties which accompany its use, so that now it is being successfully used for many purposes astounding to the uninitiated.

The gyroscope consists essentially of a heavy wheel rotating with little friction on an axle which is so mounted in a system of rings that it is free to turn in any direction. Such a wheel, when rotating at a high speed, will perform many surprising antics, such as running down a stretched string without falling over. Completely to understand why a gyroscope acts as it does would demand familiarity with much complicated mathematics, and cannot be attempted here. What we can do, however, is to describe how a gyroscope may be expected to act in certain simple cases.

The fundamental principle of the gyroscope is a simple one, familiar to all of us. It is that when a body is rotating about an axis it tends to keep on rotating about the same axis, and that it takes some force to make it rotate about a different axis, or to change the direction of the axis about which it started to rotate. A familiar example is afforded by the game of quoits. We all know that we are much more likely to ring the peg if, when we throw the quoit, we give it a twist. When we give it such a twist, we start it rotating about an axis, and this axis tends always to preserve its original direction, so that the quoit hits the peg at the proper angle. The diagram, showing the quoit in several positions, with the imaginary axis drawn, will make this clear.



THE GYROSCOPE IN ACTION

THE GYROSCOPE PRINCIPLE ILLUSTRATED IN A GAME OF QUOITS

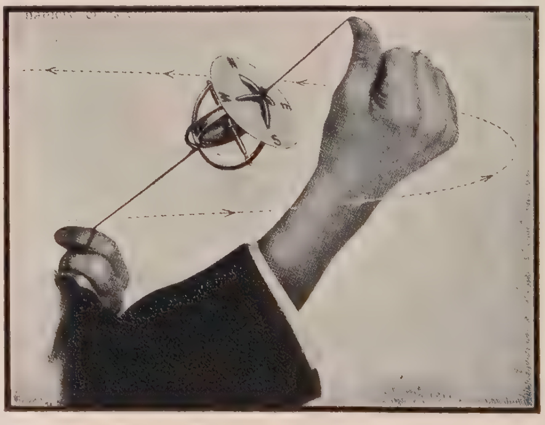
The twist given the quoit as it is thrown, starts it rotating about an axis, which tends to make it preserve its original direction.

THE PRINCIPLE APPLIED TO THE COMPASS

This, then, is the first principle of the gyroscope; that the axis, so long as the gyroscope is turning, tends always to point in the same direction. Let us now apply this principle to a practical case which will suggest one of the applications. Suppose that we have a heavy gyroscope, so skillfully constructed that it will run a long time, perhaps several days, without stopping. Now let us start this gyroscope some morning toward the rising sun, with its axis fixed pointing east and west. Then as the day goes on the axis of the gyroscope will continue to point towards the sun, apparently tilting upwards until at noon it points up and down. Though at first it seems as if the gyroscope did change its direction, it really does not but continues to point towards the sun while the earth rotates under it.

But now let us suppose that when we start the gyroscope in the morning, we point it at the north star, instead of at the rising sun. Then as the earth revolves and the day wears on, the direction of the axis of the gyroscope will not be changed by the rotation of the earth, because the earth's axis itself always points toward the north star. The gyroscope will, therefore, remain in its original position without compulsion. This, then, is the principle of the gyroscopic compass, that if the axis of a gyroscope which is perfectly free to move is pointed at the north star, it will never tend to leave this position, and can be made to do so only by the application of some force. The earth may rotate beneath it, or the ship carrying the gyroscope may maneuver as it will; the axis of the gyroscope will always point true to north.

In the practical use of the gyroscope as a compass for navigation, it is easy to see that there are a number of technical difficulties to be overcome. For instance, the gyroscope must be made to point to the north of its own accord without being set by hand, it must be supported without friction and in such a way that it may be free always to point north, and some means must be provided for always keeping it rotating at a high rate of speed. In addition, there are numerous disturbing effects which have to be automatically corrected in some way. Such effects are due to the motion of the ship itself as it moves over the surface of the earth. All of these difficulties have been most ingeniously and successfully overcome by E. A. Sperry, the inventor of the Sperry Gyro-Compass. This compass is now in successful use, especially on battleships, where it has particular advantages over the old magnetic compass. The reason for this is that a battleship is made of



THE GYRO-TOP, SHOWING THE PRINCIPLE OF THE GYRO-COMPASS steel, which itself attracts the magnetic needle. As a result, every magnetic compass has to be particularly adjusted for the individual ship on which it is to be used. But in time of battle, large masses of metal are likely to be displaced by the enemy's gunfire, so that the compass may fail at a time when especially needed. The gyro-compass has none of these disadvantages, and has a number of other important advantages as well.

A STABILIZER OF SHIPS

Besides the gyro-compass, we owe to Mr. Sperry another important application of the gyroscope. This is in stabilizing ships. The essential idea is similar in many respects to that of the monorail car. As the ship rolls, a device automatically applies to the gyroscope a small force which calls forth a much greater force in such a direction as to counterbalance the tendency of the ship to roll. The advantages of a nonrolling ship are obvious to anyone who has traveled by sea. In addition to doing away with physical discomfort, a nonrolling ship would have many economic advantages, because it takes less power to drive a ship which does not roll. The advantages for a battleship going into action in a heavy sea are obvious. This problem has been attacked before and partially solved by some German engineers, who use for the purpose large tanks of water, in which the rolling of the ship sets up waves that tend to counteract the rolling of the ship. The gyroscope had also been tried before, but in another form. None of the early devices are nearly as efficient or as economical, however, as the Sperry stabilizer.

STEERING TORPEDOES AND STABILIZING AIRPLANES BY THE GYROSCOPE

Finally we may mention two other important uses of the gyroscope. The first of these is perhaps the first use to which it was put; namely, in steering torpedoes. This was first done by Obry, an Austrian naval officer, and is now used in practically every type of torpedo. The torpedo is kept true to its course under water by an undeviating gyroscope so connected with the rudder that it keeps the torpedo always in its own direction.

The other application is in stabilizing airplanes. At first, inventors seemed to have the idea of keeping the airplane on its course by the sheer brute force of a gyroscope, which should grasp the airplane in a giant hand and compel it to preserve an undeviating direction. But it was soon proved mathematically that this would require a heavier gyroscope than any airplane could carry. Recent attempts, however, are more successful. One of these is the Sperry airplane Gyropilot. This consists of two gyroscopes so connected with the levers of the various controls that when the airplane tends to deviate from its course the gyroscopes automatically work the levers and keep the airplane on its course, just as the aviator would work the levers if he could attend to all things quickly and surely. This has been successfully applied to a large number of airplanes. Automatic steering devices operated from the gyrocompass are also in use on some five hundred vessels of all sizes and types.

Courtesy of Sperry Gyroscope Co.

GYRO-PILOT OF A MODERN SHIP

DEVICES FOR SAVING LIFE

THE INHALATOR

WHILE in the past human life was threatened by only a limited number of accidents of certain familiar types, civilization of to-day brings a new group of dangers. For instance, we are threatened by the danger of being overcome by carbon monoxide from the exhaust from our automobiles, by fumes from gas explosions, and by electric shock. Because of these increasing dangers to man, doctors have directed their attention to testing and improving devices for saving life. They have found that a device called an "inhalator" is most helpful in treating persons poisoned by carbon monoxide gas. For many years the pulmotor was the standard equipment for use when normal breathing had been interrupted. Now, local gas companies all over the country keep inhalators, which are small enough to be carried easily in an automobile, for use in case of sudden accident.

Suppose that a member of your family were overcome by the exhaust from his automobile. He should, of course, be brought out into the fresh air at once, and the prone-pressure method of artificial respiration should be started.[1] Every moment of delay is serious, and the first few minutes are often the most valuable. Someone should telephone to the local gas company for an inhalator. When the inhalator arrives, one of the assistants will place the close-fitting mask over the patient's nose and mouth. A tube from the mask is connected with the inhalation apparatus. In this apparatus are two small tanks, one containing oxygen and one carbon dioxide. It has been found that the poisonous carbon monoxide is driven out of the body more rapidly if pure oxygen is breathed. But pure oxygen does not stimulate breathing. Therefore, a small amount (five or seven per cent) of the other gas, carbon dioxide, which we are breathing out all the time, is given with the oxygen. This gas causes the patient to breathe much more deeply, and thus a plentiful supply of oxygen is brought into the lungs.

Even when the inhalator is adjusted you must never stop your use of the prone-pressure method. It is the best means of starting normal breathing, while the oxygen-carbon-dioxide mixture from the inhalator drives the carbon monoxide out of the blood as quickly as possible.

THE RESPIRATOR

Very recently a device called a "respirator" has been developed for treatment of most severe cases, those which require a long use of artificial respiration. The respirator consists of a steel cabinet, large enough to hold the body of the patient, and electrically driven pumps which make positive and negative pressure within the cabinet. These variations in pressure compress the chest and expand it in much the same way as is done when a person gives the prone-pressure method of artificial respiration. The apparatus is large and is, of course, used only in a hospital.

THE TYPEWRITING MACHINE

TO help the blind to read! How many of you have ever thought of this as being the purpose for which the typewriter was originally designed? Yet the early inventors had this noble motive in mind more than one hundred years before Christopher Latham Sholes, "the father of the typewriter," brought his first crude writing machine to public view.

First, efforts were to fashion machines that would print raised letters on paper — letters and words which the blind could read by the touch of their sensitive finger tips. As early as 1714 we find an English engineer patenting a machine for impressing letters on paper. In France and America other ingenious minds were attempting to solve the same problem. Others realized the value that a true writing machine might have in business, and from the work of half a dozen inventors during the next century and a half came several devices that are used in principle in our typewriters of to-day. For instance, an American inventor, Charles Thurber, made a workable typewriter in 1843, using a sliding carriage to hold the paper and a device for turning the paper when a line was finished. The type bar, now a part of every writing

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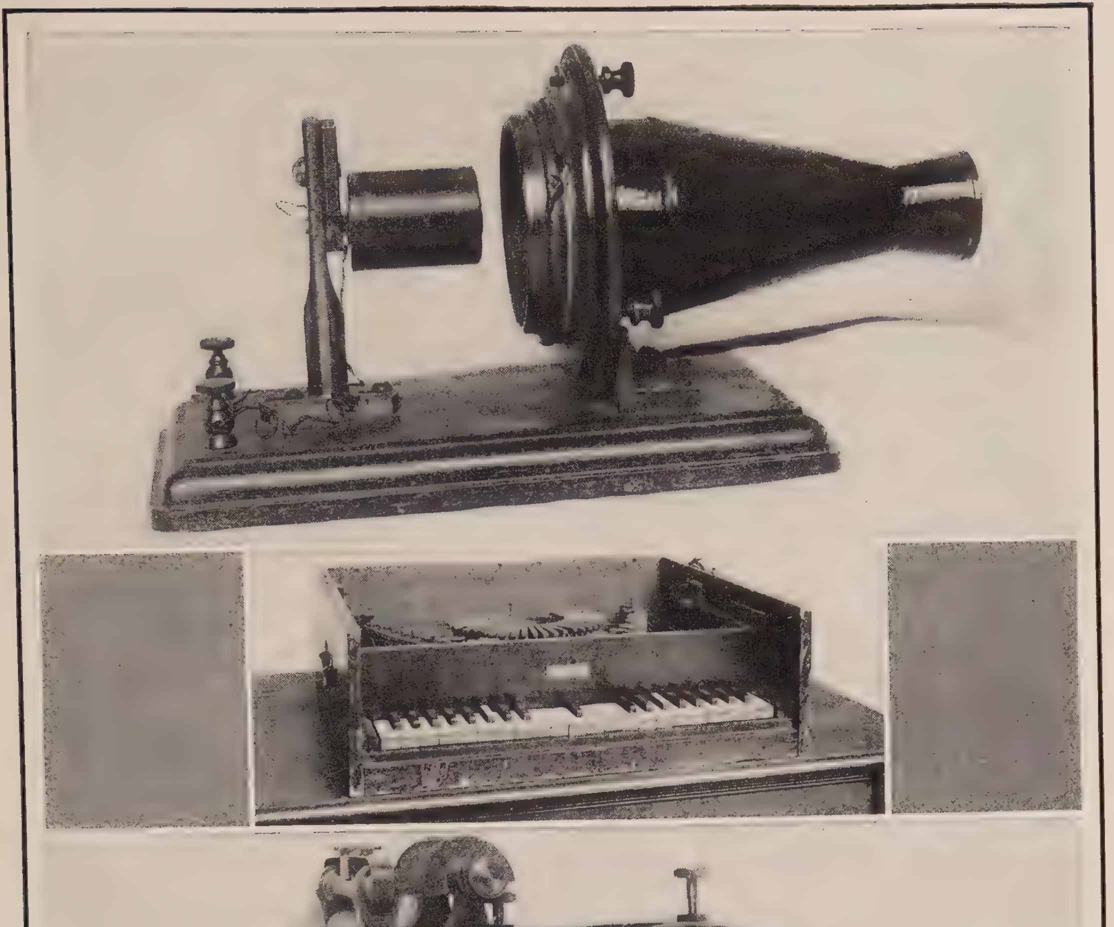
[1] *See* Volume VI, page 88.



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FIRST MODELS OF FAMOUS INVENTIONS

Top: Alexander Graham Bell's telephone, the model submitted in 1876. Center: An early typewriter, with keyboard like a piano. Bottom: The Morse telegraph instrument used on the Washington-Baltimore line, May 24, 1844.

machine, was found in a machine invented about the same time by Progin, a Frenchman. Alfred E. Beach, another American, built a number of machines about the middle of the nineteenth century. Still another American, John Pratt, then living in London, built a typewriter in 1866 that was an improvement over earlier attempts, and was widely discussed.

THE WORK OF SHOLES

Christopher Latham Sholes, a man well known in Milwaukee, was the genius whose patient efforts were finally to produce and develop the machine with which we are all familiar. In 1867 when he first demonstrated the principle of his typewriter to friends, Sholes was collector of customs in his city. He was an inventor whose life had been broadened and enriched by a variety of occupations and by contact with many people. He had been an editor, a publisher, a printer, and had held many public offices.

The work of making this first real typewriter was not entirely that of Sholes. To help him he called upon Carlos S. Glidden, who had aided him in perfecting a numbering machine, and a machinist by the name of Samuel W. Soule. These were the men to whom he showed his first machine. The original model was made with an old telegraph key, some wood, and a piece of glass. It had one letter, "W," carved at the end of the key. By pressing the key, this letter was made to strike through a piece of carbon paper and was imprinted on some white paper held against the glass.

Several months of work produced the first complete machine. As will be seen in the illustration on page 167, it had a row of keys similar to those of a piano. On these the letters were indicated with paint. This machine, queer-looking as it was, contained a number of the principles found in the improved mechanisms of the modern day.

The first steps toward improvement were made in the keyboard, which was finally arranged in four rows, much as is seen to-day. For five years the three partners made change after change and improvement after improvement. James Densmore, a Pennsylvania business man, became impressed with the possibilities of the machine and purchased a quarter interest in the business. Trial in actual use showed weaknesses that were soon corrected. The difficulties of the work, however, were too great for their limited facilities. It was suggested that a firearms maker might have the skill and equipment with which to make the machine of practical value. The Remington Arms Co., of Ilion, N. Y., studied and worked on it. So pleased were they that they purchased the machine from Sholes and Densmore and soon had developed it to the point where it could be actually marketed.

BUILDING THE MODERN TYPEWRITER

Sholes died some years later, but the difficult work of interesting the business world in this new machine was in capable hands. Of course the first machine wrote only capital letters. The first attempt to make a typewriter printing both capitals and small letters resulted in a machine with a double keyboard — a key for each character. Following this came the machine using the "shift key," by which both kinds of letters could be printed with a single set of keys. In the first machine it was also necessary to raise the roller in order to see what had been written. This defect was remedied by Franz X. Wagner's invention of the "visible" typewriter, which in a few years had replaced the earlier models.

From these first machines has been developed a host of typewriters for many uses. In modern business there is no machine more important than the typewriter. How far the compact mechanism of to-day has come from the original crude devices, made to help the blind to read!

INDUSTRIAL PIONEERS

THOMAS EDISON

(1847–1931)

ONE night in 1868 a young telegraph operator, named Thomas Edison, hurried into his hall bedroom in Boston with a secondhand set of Faraday's works. It was four o'clock in the morning, but he read until breakfast time. Then he remarked to his roommate, "I have got so much to do and life is so short, I am going to hustle." With that he started on the run to his boarding house.

Now, in looking at the achievements of the man Edison, those words have an almost prophetic ring. At that time he was just twenty-one, but he had used those years to good purpose. Before he was twelve years old, he had fitted up a laboratory in his mother's cellar in Port Huron, Michigan. In order to earn money to buy chemicals for his experiments, he became a newsboy on the railroad.[1] He had learned telegraphy when he was fifteen and had worked in various telegraph offices over the Middle West before he came to Boston. In Boston the days were never long enough. Outside of the hours spent in the telegraph office, he was always studying and experimenting. Usually he stretched his day to eighteen or twenty hours.

These books of Faraday's spurred him on. He liked their clear explanations, and soon he had repeated all Faraday's experiments. But repeating what other people had done was not enough. When he was just twenty-two he patented his first invention, a vote recorder. Although this was a satisfactory machine, no one was interested in it. Hereafter, young Edison decided he would invent only those things which people really wanted.

In order to carry out his desire to be an inventor, Edison went to New York. His arrival in that city reminds one of Franklin's arrival in Philadelphia. But Edison did not even have money enough to buy his breakfast. As he walked up the street he passed a warehouse where a tea-taster was inspecting teas. He asked the taster for some of the tea. The tea which the man handed over to him was his first meal in New York.

A year later Edison had so well demonstrated his mechanical and inventive ability that he was managing a large shop in Newark for the manufacture of stock tickers and their parts. At the same time he was working on new inventions in his laboratory. People had not been long in discovering that he was a man who could tell what was wrong with any mechanical device and could figure out improvements for it. All sorts of problems were brought to him.

There was the matter of the telegraph. In many respects it had never been completely satisfactory. Edison worked out the desired improvements. He also made possible quadruplex telegraphy in which one wire does the work of four — that is, four messages, two in each direction, may be sent at the same time over one wire. To Bell's telephone he gave a new transmitter which made it "speak out loud and bold."

THE PHONOGRAPH

In 1877 when he was just thirty he invented the phonograph.[2] Never before had there been a "machine which could talk." When this invention became known, people flocked to his laboratories at Menlo Park, New Jersey. Many of them thought that the machine must be a fraud. Edison allowed them to talk into the recorder and then turn on their own records. Among the people who came was a minister who had resolved to make a test which would reveal the truth. He talked into the recorder a long collection of proper names from the Bible just as fast as he could. Much to his amazement these came back to him in his own voice, each word correctly repeated. That convinced him that Edison was not deceiving anyone, for no one else in the country could recite these same names with the same speed. He, as well as other people, had thought that a ventriloquist must be concealed in the laboratory to repeat the words which were said. The newspapers dubbed Edison "The Wizard of Menlo Park."

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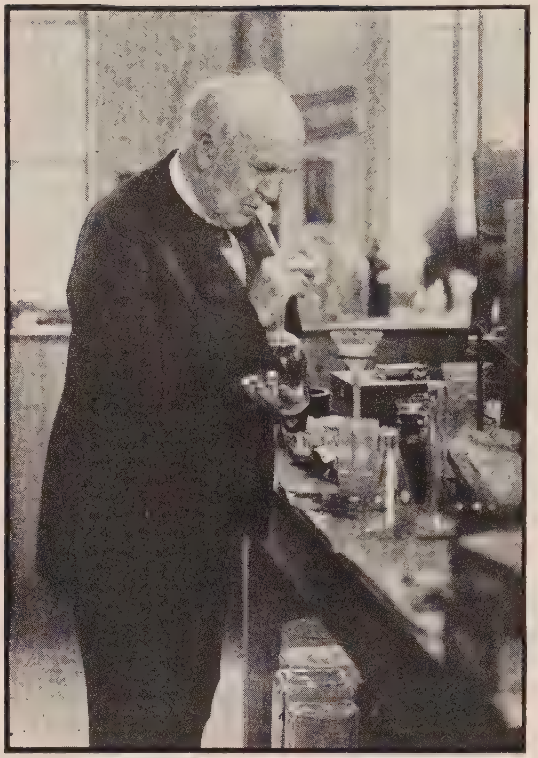
[1] *See* Volume VIII, pages 85–90.

[2] *See also* "The Phonograph," on pages 162–163 of this volume.



Underwood & Underwood

EDISON IN HIS LABORATORY

ELECTRIC LIGHTING

From this time Edison has often been referred to as "the wizard." The name was applied even more frequently after he developed the present system of electric lighting. In 1878 when he began his work, the only electric lights in use were so very bright that they were not only unpleasant but also harmful to the eyes. For a good many years Edison had thought that it should be possible to produce electric lights in small units, or lamps which would give a light like that from the gas jets then used. He prepared for his invention by studying everything that was known about electric lighting and also everything that had been written about gas lighting. From the time of his reading of Faraday's books in Boston, he had been impressed with the necessity for careful study. More than two hundred notebooks were filled with his notes — a total of over forty thousand pages. Then, under his direction, a staff of forty or fifty brilliant young men carried on a long series of experiments in his laboratories. It is said that they worked all the time. No one slept more than four or six hours. Although the work was tiresome, they were devoted to Edison, and they believed in what he was trying to accomplish. We know how successful these experiments were. At that time, however, there was a great deal of scoffing about what was going on at Menlo Park.

When the first public exhibition was given on New Year's Eve, 1879, people came and marveled. It seemed indeed like magic to find the strange incandescent or "glow-lamps" hanging on wires stretched from one leafless tree to another. Although Edison had proved that electric lighting was possible and practical, innumerable parts had to be invented before a whole lighting system, such as we have in every city and village, could be established. In the year 1880 alone, sixty patents relating to electric lighting were applied for by Edison. He was never satisfied until his inventions were as perfect as possible.

For instance, the carbonized filament in these first incandescent lamps did not seem entirely successful. In the laboratory one day, early in 1880, he picked up a palm-leaf fan and examined it. Suddenly he tore off the long flexible strip of bamboo which bound the edge of the fan. This he gave to an assistant with instructions to divide it into the largest possible number of pieces suitable for carbonizing into filaments. These filaments proved better than anything used thus far. But, thought Edison, there may be something in the world which is even better. In order to find out, he spent approximately $100,000. Representatives were sent to China and Japan, to the forests of lower Brazil, to Cuba, to Peru, Ecuador, and Colombia, to Ceylon and India. It is said that his fiber-hunt "put a girdle around the earth." From the material collected, Edison chose a special kind of Japanese bamboo which was used for many years. Then he perfected an artificial filament which proved to be the best for the commercial production of lamps.

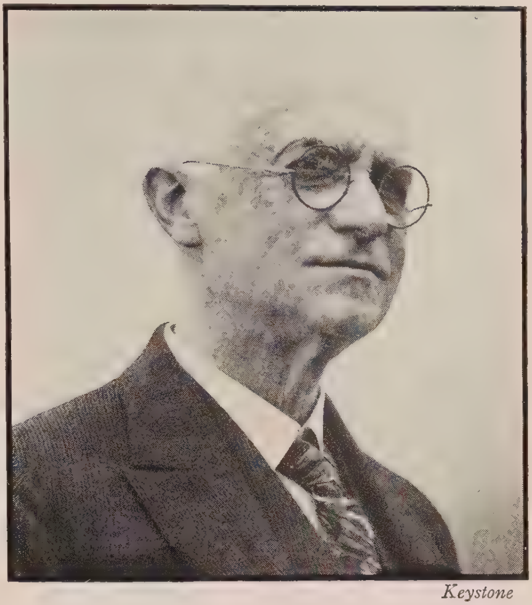
In 1887 Edison moved to West Orange, New Jersey, and established himself in a new laboratory. At that time it was the most perfect in the world. Besides the laboratory, there was a special research library and a huge stock room with every sort of material which might be wanted in experimenting. One of the first inventions which came from this laboratory was a moving-picture camera. Edison had long wanted to make an instrument which would do for the eye what the phonograph does for the ear. During the summer of 1889, the first motion pictures were taken.[1] The kinetophone, which we commonly call the talking-motion picture, was introduced in 1912.

During World War I, at the request of Josephus Daniels, Secretary of the Navy, Edison became advisor to the Naval Consulting Board of the United States. It was the duty of this board to pass on the ideas and suggestions which were submitted to the Navy Department. For two years Edison gave up all his personal work to study plans and developments of inventions which might be useful in war. Among other things which he invented was the listening device for detecting submarines.

HUNTING FOR RUBBER

In his last years Edison realized that with the great increase in the use of rubber tires on automobiles and trucks and with all the other thousands of important uses of rubber, an unfailing source of rubber supply is very important. He tested sixteen thousand different plants, all of which could be grown in the United States, and found a number that would yield rubber. Because it was cheaper to import rubber from the East Indies, Edison's experiments were not followed up commercially. Our nation had cause to regret this when in World War II the Japanese seized the rubber plantations of the East Indies and cut off our rubber supply.

Edison's death on October 18th, 1931 caused world-wide mourning, but his fame as an inventor and the great industries which he made possible can never die. He had "so much to do," but he always seemed to like doing it. On his seventy-seventh birthday, Edison was asked to tell his philosophy of life. He wrote briefly: "Work. Bringing out the secrets of nature and applying them for the happiness of man. Looking on the bright side of everything."


Keystone

GEORGE EASTMAN

(1854–1932)

GEORGE EASTMAN was twenty-three years old when he spent $94.36 for "sundries and lenses" and arranged with the local photographer in Rochester to teach him the art of photography. At that time he was the junior bookkeeper in the Rochester Savings Bank. He had started working for himself when he was fourteen. His first job in an insurance office had paid three dollars a week. Now he had saved a little money, and he decided to have some fun outside his working hours.

After he had learned to take pictures, he often went on excursions with his outfit. Anyone who took pictures at that time had to make his own "wet plates"; moreover, these plates must be used as soon as they were made. In speaking of the first pictures he took out-of-doors, Eastman said, "One did not 'take' a camera; one accompanied the outfit of which the camera was only a part." His outfit consisted of a large square camera, a tripod which was "strong and heavy enough to support a bungalow," a big plate holder, a dark tent for developing, and a quantity of chemicals.[2]

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[1] *See also* "Motion Pictures," on pages 151–158 of this volume.

[2] *See also* "Photography," on pages 143–146 of this volume.

One day he read in a British magazine a formula for making a sensitive gelatine emulsion with which glass plates could be coated so that they could be used when they were dry. He knew very little about chemistry and mathematics, but he was eager to take good pictures. The problem of making a satisfactory dry plate fascinated him. Like Ford, he worked at night, frequently all night long, and slept on Sundays. At last he worked out an emulsion that could be coated and dried on the glass plate and still retain its photographic properties long enough to be used in the field. With a satisfactory plate for his own use, the possibility of producing plates to sell came into his mind.

In 1880 three years after he bought his first equipment, Eastman gave up his position in the bank and went into the business of making photographic plates. He fitted up a laboratory where at first he did all the work himself. His dry plates soon became famous. But Eastman was not satisfied. In many ways glass plates would always be difficult to use, and it certainly was hard to ship them safely. There ought to be something which would take the place of glass. He sent experts all over the world searching for paper and other raw materials. At last he found what he wanted. The first commercial film, the predecessor of the flexible film which we use to-day, was manufactured on March 26, 1885.

While the film experiments were going on, Eastman was also planning for some sort of light portable film camera. The first "kodak," as he named it, was placed on the market in June, 1888. In 1889 the Eastman plant received an order from the Edison Phonograph Works for one of the new kodaks. Edison had recognized the possibilities of the flexible film for making motion pictures. Edison made the first motion-picture camera, but Eastman made the first reel of film for it. The interesting fact is that neither of these men knew what the other was doing. Within a few months, however, their contributions were combined to produce the first moving picture.

Mr. Eastman never considered his work done. He was always seeking to make a better product and to lessen the cost of manufacture. His constant aim was to make the taking of pictures easy for everyone.

HENRY FORD

(1863–)

HENRY FORD was born on a farm in Michigan not far from the city of Detroit. The farm was a delightful place for a boy, but it was also a place where a lot of good hard work must be done. By the time he was twelve years old, Henry was doing almost a man's work. He did his part in the plowing, haying, and threshing, but he dreamed of a machine which would pull loads and possibly even plow. Perhaps some day, he thought, a steam engine might be used in place of horses.

He had never forgotten his first sight of a steam engine. He and his father had been driving to Detroit when they met a road engine which was driven, steered, and fired by one man. When the man saw the horse and wagon coming, he stopped the engine so that the horse might pass without being frightened. This was the first motor car which had ever come down their roads, and the boy dashed over to ask the engineer all about it. The man kindly explained how the machine worked, and Henry was immediately fired with the desire to make an engine himself. He had always fooled with tools in the old workshop on the farm. A little later, he did build out of metal scraps an engine which really worked.

When he was seventeen, Henry decided to leave home and find a position in the machine shops of Detroit. An apprentice mechanic could make only $2.50 a day, and the boy's father thought he would not stick to such a job. However, the work with machinery made young Ford perfectly happy. At first, in order to add to his income, he spent his evenings repairing watches in a jewelry store. He liked tinkering with watches and gradually made a collection of them. These he studied, comparing kinds and makes. Then he decided that if all the parts of a watch were made by machinery in great quantities, the material in any one should cost only a little more than thirty cents. Suppose he could make two thousand watches a day and sell them for fifty cents! The idea fascinated him, but he finally decided that watches were n't so generally necessary and probably he could n't sell all he could make.

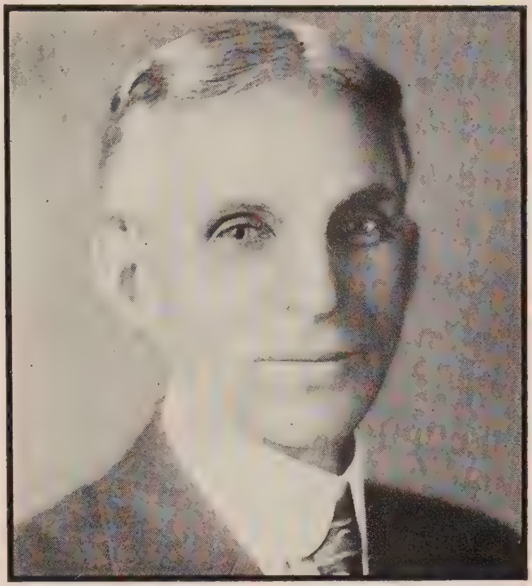
The interesting thing about the scheme is that even then Ford was wanting to make something in quantity.

After four or five years in Detroit, he went back to the farm. He was n't particularly interested in farming, but he did want to experiment with engines. In the technical journals he had been reading about the gas engine which had been invented in England and about the possible use of gasoline for fuel. His plan was still for an engine that would help with the work on the farm. He built various engines in his workshop, but no one else was interested in a machine for farm work.

In 1890 the desire to work with machinery brought him to take a position with the electric company in Detroit. As soon as his work with the company was going well, he began working nights on a "horseless carriage" with a gasoline engine. At that time his wife was the only person who had faith in his ability to do what everyone else said was impossible. Although many people, both in England and America, were working on carriages of the same sort, Ford did not know what lines they were working on or what they were accomplishing. Everything that he did was carefully worked out beforehand. Much of the first car was made of junk. For instance, the cylinders of his motor were made of the cast-off exhaust pipe of a steam engine which he bought from the electric company; the wheels were four old twenty-eight inch pneumatic-tired bicycle wheels.

Three years of evening work, and in April, 1893, Ford felt that his car was in running order. It was past midnight and raining hard, but he could not wait until morning to try it out. Mrs. Ford took her umbrella and went out to see what happened. Sure enough the car moved; it ran; it was a success. Ford drove down several streets with Mrs. Ford walking along beside him.

This "gasoline buggy" was the first car to be driven in Detroit.[1] Whenever Ford went out in it, a crowd gathered. If he left it, some curious person would be sure to attempt to run it. At last he had to carry a chain with him and fasten the car to a tree or lamp post while he was gone.


Hartsock

FORD, INVENTOR AND INDUSTRIAL LEADER

Although people were interested, they did not see that there was a future in Ford's curious little carriage. A car would be too expensive for most people they thought, and they laughed when he said, "I 'm going to make them so cheap that everybody can have one."

Ford did not go into the automobile manufacturing business until 1899. Then he became the chief engineer of the Detroit Automobile Company. Since this company was interested in making only high-priced cars, Ford resigned after three years. He had no money to start a company of his own, but he was sure that he wanted to make a small light car which would be useful to everyone.

At this time people were excited about racing cars. In order to attract attention, he built a racing car. In 1902 Ford won a race in a car of his own make. A year later a Ford car won another race. This proved to Detroit that Ford knew how to do things with cars.

In 1903 a group of business men in Detroit furnished the capital to start the Ford Motor Company. For several years the company went through difficulties. Often there was barely enough money to pay running expenses. Some of the men wanted to give up the idea of making a cheap car, but Ford held to his idea that profits and financial matters would take care of themselves if he could make a good car that would be cheap enough for the average man. He was skillful in buying materials and his workmen had faith in his ability. They would stand by him in whatever venture he made. By 1908 he was building a hundred cars a day and could not keep up with the orders. Then people had to admit that Ford's idea of "utility and service" was not so foolish after all.

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[1] *See* the first Ford Car on page 103 of this volume.

From year to year the models were altered, but always Mr. Ford studied closely the results of every change. Every detail must be tested and not a feature based on guess or theory. He worked on the same principle when he built the Fordson tractor. To be able to furnish a machine for farm work made him particularly happy.

During this time, Ford was also working to devise labor-saving machinery which would make work easier at the plants. He never forgot that he was once a mechanic working for wages. In 1914 he carried out a plan to share profits in his company. There was an uproar in Detroit when it was announced that the lowest-paid employee of the Ford Company was to receive five dollars a day for eight hours' work. Since then he has worked out other plans to take care of his men and to have his plants the most healthful and efficient ones in the world. He believes that all people are bound together like parts of one machine and that if all men work together the world can be made a better place for everyone.

ALEXANDER GRAHAM BELL

(1847–1922)

If Alexander Graham Bell had not been a teacher of the deaf, it is probable that he would never have invented the telephone. His father and grandfather had both been teachers of correct speech and elocution in England and Scotland. Young Alexander was merely carrying on the family tradition when, at the age of twenty-four, he became the chief lecturer in the School for the Deaf in Boston. Here, he used the system invented by his father called "visible speech." By this means deaf people who had never heard a sound in their lives could be taught to speak when they were shown in what positions the mouth, lips, throat, and tongue were held to make sounds.

Teaching and the way in which sound was made were the two chief interests of young Alexander Bell. He had begun his own teaching in a small private school in Scotland when he was barely sixteen. A little later when he went down to London to visit his father, he met Sir Charles Wheatstone, the inventor of the English telegraph. Naturally, the telegraph with its short and long clicks coming over the wire interested him. At that time he thought it ought to be possible to make a musical telegraph with as many keys as a piano. By playing different tunes on the keys, it seemed to him that several messages could be sent over the wire at once.

However, he dropped the idea when the family moved to Canada. After he went to Boston in 1871, he was too busy at first with his teaching to think of his musical telegraph. But in 1874 two friends became interested in his idea and agreed to back his experiments. He did not give up his teaching, however. He was constantly wishing to do something further for the deaf children of the world. While working on the musical telegraph, he decided that it should be possible to invent an apparatus which would help deaf people to get the vibration of sound. His plan for the telephone, the idea that one person could talk into an electrified wire and have someone at the other end hear the words as they were spoken, grew out of these two ideas. But no one else saw its possibilities. Even his two friends were unwilling to have him take time from the musical telegraph. Most people thought that this brilliant young teacher of twenty-seven was wearing himself out with crazy experiments. But Bell could not give up his idea.

With his one assistant, young Mr. Watson, he worked every spare moment in the attic of an electric shop in Boston. Test after test was made to bring sound over an electrified wire. Finally, one June day in 1875, a faint sound came to Bell from his assistant. Probably he would not have recognized the importance of that chance sound had his ears not been trained to catch the smallest sound vibration. He was thoroughly excited and surprised Mr. Watson by dashing into the other room crying, "What did you do then? Don't change anything. Let me see." For ten months Bell worked over the discovery made on that June day. It was on March 10, 1876, that Watson waiting in the basement at the end of the electrified wire heard Bell who was in the attic say at the other end, "Mr. Watson, please come here. I want you." Watson dropped the receiver and dashed up the three flights of stairs crying, "I can hear you. I can hear the words."

The first telephone had been invented.[1] It would seem that the world must see at once that a remarkable thing had been accomplished. But people are always slow to recognize a new thing. This was the year when the Centennial Exposition for the celebration of the one-hundredth anniversary of the signing of the Declaration of Independence was opening in Philadelphia. One of the friends who had helped to furnish money for the experiment got an odd corner in which to exhibit the machine. For six weeks people passed in and out of this building, but there were so many other things to see, no one had time for the queer little machine which sent words over a wire. It seemed nothing more than a plaything anyway.

It was the duty of the judges of the exposition, however, to examine every exhibit. Alexander Bell arranged to be there on the day of their visit. By the time they reached the corner where Bell was waiting it was evening and they were hot and tired. They looked at the machine but made no attempt to see what it would do. Fortunately for Bell, the young Emperor of Brazil, Dom Pedro, was one of the unofficial observers going around with the judges. He had met Mr. Bell some months before in Boston and had been much interested in the work which he was doing for the deaf. Now he greeted the young professor enthusiastically and inquired what had brought him to the exposition. Bell showed the machine to him, explained how it worked, and then went to the transmitter the width of the building away. He began speaking Hamlet's soliloquy which had long been a favorite in his family. "To be or not to be, that is the question," came clearly over the wire. One after the other the tired judges listened and repeated the words of the speech which they heard. When Bell had finished, they were all marveling at the sound of the human voice coming over five hundred feet of electrified wire. They forgot their weariness and stayed for several hours while they took turns listening and talking into the queer instrument.[2]

Keystone

ALEXANDER GRAHAM BELL IN 1892

Opening the first telephone line between New York and Chicago.

No longer did the telephone have to hide away in a dark corner. It was placed in the judges' pavilion and Bell received an award for his invention. A number of years passed before the world awakened to the great possibilities of this invention. But at last merited honor and reward came to Bell.

. . . .

In January, 1915, he sat in New York at an instrument which was a perfect reproduction of the first telephone. The transcontinental telephone line had just been completed. In San Francisco Mr. Watson sat at the other end. Bell spoke into the machine, "Mr. Watson, please come here. I want you." It somehow seemed fitting that the first message to go across the country in opening the telephone line should be the same as that which had startled Mr. Watson on that long ago March day. Only it was necessary for him to answer this time, "It would take me a week now."

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[1] *See also* "The Telephone," on pages 76–83 of this volume.

[2] *See* the model of the first telephone on page 167 of this volume.

It is impossible to end the story of Alexander Graham Bell without speaking of his interest in aviation. Beginning in the nineties, he experimented at his summer home in Canada with heavier-than-air craft. His models, mostly variations of kite forms, have never worked out in practice. But his faith in flying, at a time when mechanical flight was laughed at, was a great help to young fliers. He was a friend of Professor S. P. Langley who would probably have been successful in 1903 had an accident not befallen his large machine. Bell and his wife were instrumental in forming the Aërial Experiment Association with four enthusiasts in 1907. Among these young men was Glenn H. Curtis who flew the third machine made by this group on July 4, 1908 and won the trophy offered by the *Scientific American* for a heavier-than-air flying machine. Bell's only actual contribution to aviation was the pontoons for starting and alighting on water which were developed in the first seaplane.

MARCONI

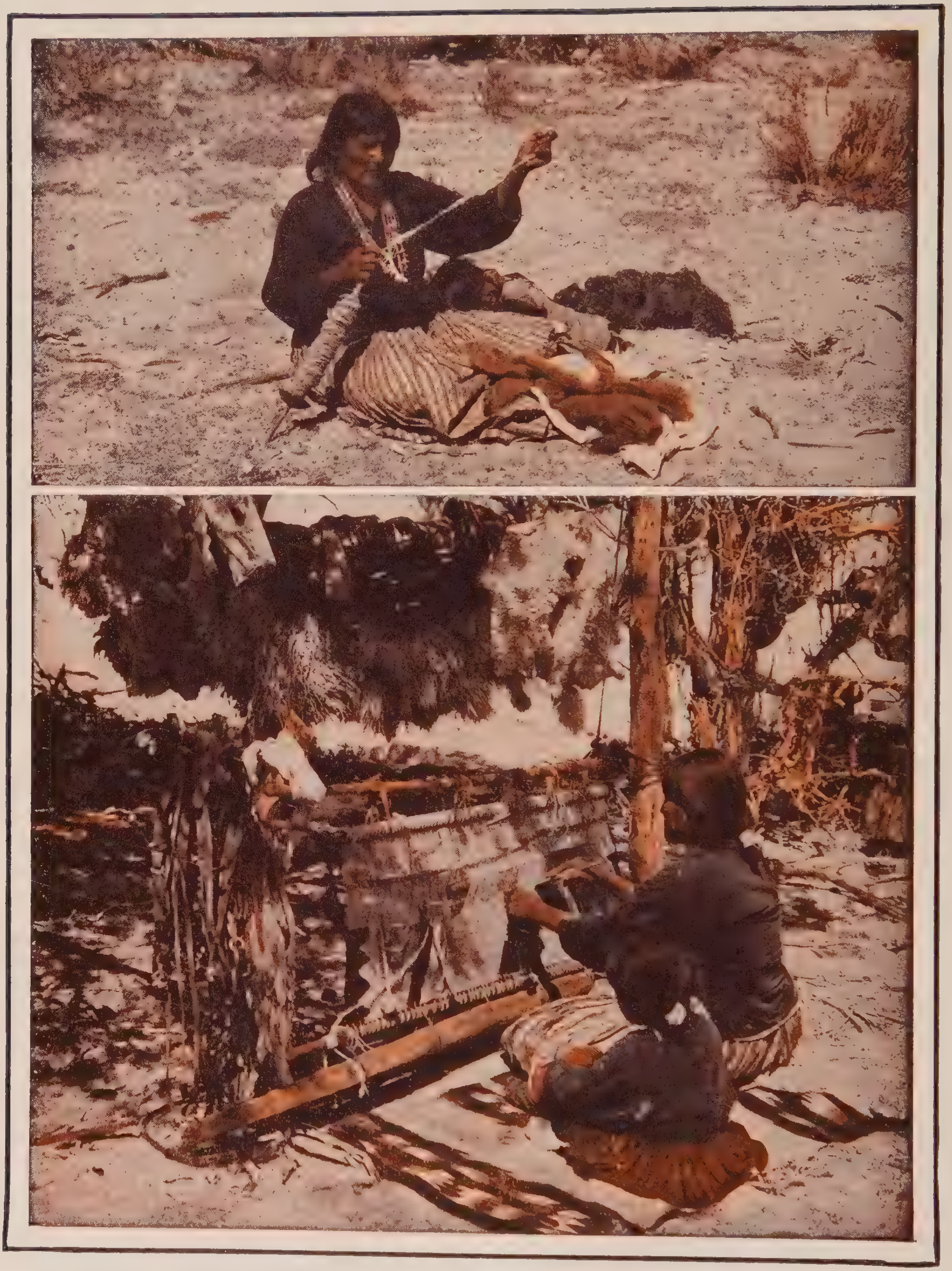
(1874–1937)

GUGLIELMO MARCONI was born near Bologna, Italy, on April 25, 1874. His father was Italian and his mother Irish. The boy went to school not only in Bologna and Florence but also in England. When he was very young the power of electricity fascinated him. From one of his Italian teachers he learned about electromagnetic waves and the attempts which had been made to send messages without wires. To the lad such a means of communication seemed entirely possible and practical. Every scientific book and magazine that fell into his hands was read eagerly. He expected some day to find an announcement that messages had been sent successfully by means of these waves. Surely some older scientist must be making that discovery. But this report never appeared.

When he was just twenty-one he began his own experiments, at his home near Bologna. His father encouraged him and furnished the funds with which he bought his apparatus. Marconi's first messages were sent only from room to room. Then he set up poles on opposite sides of the garden. On them he mounted simple sending and receiving instruments. As soon as he could send messages across the garden, he attempted longer distances. Even then he was dreaming of sending messages across countries, across continents, and even across the ocean. By the end of the year, 1895, he was able to send messages over a space of several miles.

The next year he went to England and on June 2, 1896, took out the first patent ever granted for wireless telegraphy based on the use of electric waves. Numerous tests and experiments to demonstrate the possibilities of wireless communication were undertaken in London. When they were successful, stations were set up around the British coast and in eastern Europe.

In 1901 the first message to cross the ocean came from Poldhu, England, to St. Johns, Newfoundland. Marconi himself came to America to superintend the erection of a receiving station. Since it was too expensive to build a great aërial for the test, kites were used to carry the wires to a great height. Then the wire was carried into a small government building. Here, when all was ready, Marconi sat ready to receive the message. He had not the slightest doubt that it would come. The operator at Poldhu had been directed to send simply the letter "s." Marconi held a telephone receiver at his ear, because this was more sensitive than the relay and Morse instruments. Although he was calm, everyone else was tense with excitement. Finally the message came, three ticks in the telephone receiver indicating the letter "s." And Marconi had proved to the world that messages could flash across the ocean. (You may read of the great development in radio communication on pages 83 to 93.)



SPINNING AND WEAVING, TWO OF THE EARLIEST INDUSTRIES

"TO THESE BELONG THE WORLD AND THE FUTURE."

INDUSTRIES AND OCCUPATIONS

All these trust to their hands: and every one is wise in his work. Without these cannot a city be inhabited. They will maintain the state of the world, and their desire is in the work of their craft.

Ecclesiasticus.

THE germ and subsequent progress of the world's industries had their birth in and were fostered by men's combat against Nature. Had he been born a satisfied being, with no wants which cried out for gratification, he would have entirely lacked the incentive for seeking in the universe about him the answer to his needs. But life was no such uninteresting existence. On the contrary, it was a stupendous conundrum — man being the questioner and the great world the silent response to his queries.

"How shall I keep warm?" asked Man.

"How shall I satisfy my hunger?"

"How shall I protect myself from the elements?"

Mother Nature heard the cry of her child, but she offered no reply. Instead, she dumbly spread out before him her wealth and left it to him to appropriate what he would. Wrapped up in that speechless universe lay the solution of every enigma puzzling him. The key to the riddle he must find himself. Through his ingenuity lay the only path out of his difficulties. He gazed out upon his surroundings with wondering eye. What should he do with the minerals, the plants, and the animals that confronted him at every turn? Since no other means for subsistence was provided it must be possible to convert them into the things he needed.

And so from crude beginnings he struggled with his glorious problem, constantly discovering new uses for the materials that lay at his hand. Gradually he discarded the skins that covered his body for spun cloth, the tent for the roofed-in shelter, the moccasin for the shoe. As the world was peopled, more minds united in solving these puzzles. How could articles be made more quickly, easily, and strongly? No single person could perfect each individual trade, and therefore it followed that while one man bent his efforts to the making of cloth, another turned his attention to making paper. So through centuries of groping experiments the upward climb to our present-day civilization was made.

Then the population of the world increased, and there arose a mighty clamor for great numbers of the commodities that had previously been turned out in small quantities. Machinery displaced hand labor, and since processes became very complex it was no longer possible for one person to begin an article and carry it on to its completion. Instead, each man became a specialist, performing his minute share in the mighty "team work" of the modern industrial world. By constant practice he became an expert in his particular part of the great process, never seeing the finished product, but ever toiling bravely under the motto, "Each for all, and all for each."

While he made cloth for his brother, his brother made shoes for him; and with those brothers who needed what he made and made nothing in return he exchanged his wares for some service he himself had no time to perform — the lighthouse keeper who made it possible that the merchandise he turned out might be shipped to its destination with safety, the fisherman who brought him food, the miner whose coal kept him warm.

This exchange of goods for goods, or barter, as it is called, was the earliest form of trade. It is still in use among primitive peoples, who exchange what they have in plenty for what they lack and want. We read, for example, of the Indians who traded furs for beads or knives. Some of us can remember how the farmer, carrying his load of eggs or vegetables to the crossroads store, exchanged them for sugar, coffee, cloth, or other materials of which he had need.

MONEY BECOMES NECESSARY

Barter worked fairly well while people lived simply and had few wants. But as civilization grew more complex, and more things were made, the process of exchange became more difficult. A man who made blankets might want a horse, but if the owner of the horse had no need for blankets, no trade was possible. Situations such as this brought about the introduction of money as a means, or medium, of exchange.

In the beginning, almost any article of general value or usefulness was used as money. The American Indian used wampum, or beads made from shells. In Tartary, cubes of pressed tea served as a medium of exchange, while in some of the provinces of China cakes of salt were employed.

But these materials lacked durability, and it became necessary to provide a money that could be passed from hand to hand without rapidly wearing out. Thus, metals of various kinds were introduced as money and became, like the gold and silver of our day, the chief means by which trade was carried on.

EACH FOR ALL, AND ALL FOR EACH

It is to the toilers of whom we have spoken that we owe the many comforts which we so unthinkingly accept. A thousand hands move ceaselessly that we may have food, clothing, and shelter; and as these men labor, they create the products which are the chief source of the wealth of our great land. For America's prosperity comes not alone through the riches of her forests, mines, and fields, but through the toil of those millions of patient workers who convert raw materials into the perfected products which are the fruit of our modern manufacture.

It is only as we compare our own with other countries that we really begin to understand the comfort and happiness which we enjoy. To its prosperity we owe the health and leisure which we too often accept as a natural condition of our daily lives. Work is available for almost all of our citizens; yet there is little of the severe labor that dwellers in some other lands find necessary. Our working hours have been reduced so that everyone can find some time for recreation. Education is easily secured, and is within reach of all. Our newspapers, magazines, books, and theaters bring us amusement as well as opportunities for self-improvement.

You will find it interesting to think about these things from your own point of view, and thoughtful consideration cannot help but bring home to you a picture of our land that will make you a better citizen.

FUEL FOR POWER

When we build a home with lumber, make a ball from rubber, or shape a china dish, we are doing a bit of creative work. We are taking raw products and fashioning them into desired and useful articles. But when we take wood, coal, and oil and deliberately burn them up, we would seem at first thought to be engaging in a process of destruction rather than of creation. So we would be if we tested all results by the same measuring rod. But when we come to discuss fuel, we are dealing with an output that is measured not in terms of number or bulk of articles created, but in the amount of heat, light, or power produced. A forest fire is wasteful in the extreme, for valuable lumber is used as fuel with no means of directing to good purpose the heat or the light generated as that fuel burns. But should we say the same of the burning of a cord of wood in our stoves or a ton of coal in our furnaces?

Man's primary needs are for food, shelter, and clothing. Fuel ministers directly to the first two. In our northern climate shelter would be of little avail if it were not possible to keep our houses warm, and man would return to the diet of the animal or the most primitive savage if he had to forego the privileges of cooked food. A single hour without street lights or house lights, occasioned by an accident at one of our public utility stations for electricity or gas, brings forcibly to our attention our need for light. Such are the simplest uses of fuel — for heat, for light, for cooking purposes. We substitute more modern equipment for the candles and oil lamps of our grandmothers and great-grandmothers, and new heating systems for their open fires; but all minister to these primary uses of fuel.

FUEL AS THE BASIS OF MODERN INDUSTRY

Modern man, living in an age of machinery, goes far beyond these needs in his use of fuel as an agent in his production of power. Power is what he wants above all things,—power to keep his factories going, his trains running, his steamships traveling across the seas. His ambitions are by no means satisfied by the strength of his own right arm, by the power which he can generate in his own bodily machine. He seeks to release other sources of power and direct them to furnish the means for doing work at his bidding. It is this need of power to run the complicated machinery of man's making which makes fuel the basis of modern industry. It is this need which makes nations and private companies engage in sharp contests for the possession of the oil-producing regions of the Near East and the Far East, and come almost if not quite to open warfare over the coal fields of Europe.

WOOD AS FUEL

Wood, coal, petroleum, and natural gas are the familiar fuels of our modern life. In the early days of the occupation of this country wood was practically the only fuel. Forests were abundant and easy of access. Even to-day it is said that more wood is cut for firewood than for lumber. But as the supply of wood diminishes and as the distances over which it must be transported increase with the gradual taking up of cleared land for agriculture, wood becomes a more expensive fuel.

In comparison with the other fuels mentioned it should be noted that wood is the only one that can be replenished. Wood *can* be grown; it is a natural plant product which renews itself under proper conditions. Minerals cannot be replaced. The mineral wealth of a country is a definitely limited supply, even though it be so enormous in quantity as to seem unlimited, as in these United States. Man cannot increase the stores of coal laid up in past ages; he cannot refill the oil reservoirs when he has drained them of their supply. He can plant trees; he can so limit his cutting as to allow for the natural new growth of the forests to have its chance. Whether it will be worth while when these trees have grown to maturity to use them for fuel instead of for more constructive purposes is a question for the next generation to settle; but every interest of national life demands that our forest areas be replenished as fast as they are cut, both for the supply of wood to be obtained and for the preservation of our water supply which comes from the high wooded areas.

PEAT A LITTLE USED RESOURCE

In this connection it is interesting to know that the United States has an unused fuel supply now in the making in the peat bogs which may be found in several of its regions. Coal and peat are different stages in the same general process (described in Volume X, page 59) by which organic material, or, in simpler language, plant life, is held under pressure beneath the earth or packed away from the air in swamps so that the carbon in it is kept from combining naturally with the air. The various fuels of which we are speaking are valuable for burning because they are rich in carbon. The act of burning, of combustion, is a chemical process; carbon in the fuel unites with oxygen of the air. A fire will not burn, as we say, without a good draft. It is the coming together of a substance rich in carbon and of air rich in oxygen which makes combustion possible. Our problem is to find carbon compounds which we are willing to turn to this process. Coal is a rich carbon compound, but it has taken centuries upon centuries of time, and earth conditions very different from those of the present day, to produce coal. Peat is of quicker formation and is now in the making in many parts of our country. It may prove a valuable household resource in some future day.

COAL THE FUEL OF TO-DAY

As it was said of the silent and mysterious Lady of the Lake of King Arthur's court that "her great and goodly arms stretched under" all the court to uphold it, so might it be said of coal that its mighty arms stretch under all our modern life to support and uphold it. No one who has lived through the past years of coal strikes, coal shortages, coal commissions, can have failed to get some realizing sense of this basic importance of coal. The householder knows the need of coal as a source of heat and reckons it accordingly. But the business man, the captain of industry, reckons coal in terms of power, since on its use is built up much of our industrial organization.

Photo, Ewing Galloway, N. Y.

A FOREST FIRE PHOTOGRAPHED BY ITS OWN LIGHT

Extremely wasteful, for neither the heat nor the light are turned to any economic use

Again, as in the case of other industries, it is surprising to find out how recent is this universal dependence on coal. Coal was not unknown in the ancient or medieval worlds; but the story of its modern use might be written under the heading of "A Century of Coal." The anthracite fields of Pennsylvania were known and drawn upon for domestic fuel in the late eighteenth century; but in 1825 or thereabouts coal was first used to make steam, and from that point its story runs parallel with that of the steam engine. What the steam engine has done to make transportation possible it has done through the agency of coal. What we owe to the increasing ease of transportation in the past hundred years we owe primarily to coal. Since modern industry and modern commerce depend on the speed and ease with which we shift goods from one part of a country to another and from one part of the world to another we cannot exaggerate the importance of our great national fuel supplies in our modern life. Add to this the fact that coal is essential for the smelting of our supplies of iron and that iron and steel are our leading manufacturing industries, and we have another argument for the preëminence of this fuel.

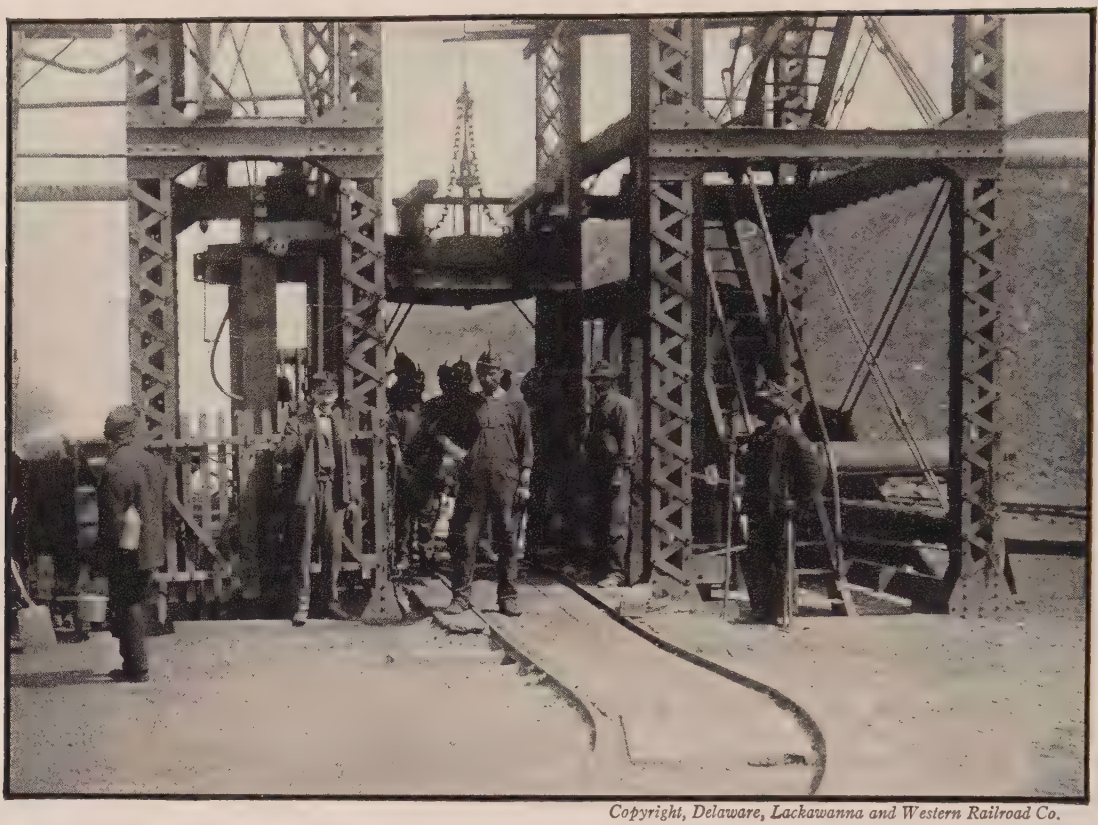
THE COAL INDUSTRY

As an industry in itself the mining and marketing of coal is not unlike other mining enterprises. The anthracite fields of the United States are concentrated in Pennsylvania within an area of five hundred square miles, with only small amounts in Colorado and New Mexico and one or two other fields. The bituminous fields are widely scattered. Professor Bishop describes them thus: "The largest, called the Appalachian, stretches from New York to Alabama, in a southwesterly direction, a distance of nine hundred miles, the field varying in width from thirty to one hundred and eighty miles. The other important fields are the Triassic in Virginia and North Carolina; the Eastern, in Indiana, Illinois, and Kentucky; the Western, including the coal fields west of the Mississippi, south of 43° north latitude, and east of the Rocky Mountains; the Rocky Mountain, comprising the areas in the states of this region; and the Pacific Coast field, embracing the coal regions in Washington, Oregon, and California. The anthracite area of eastern Pennsylvania, together with the bituminous fields of the Appalachians, produced in a recent representative year about seven tenths of the coal output of the United States."

So plentiful has seemed our supply of coal that in the past it has been mined with more or less waste and used without due regard for conservation. Although the United States is still rich beyond other nations in its supply of coal, yet it is learning from its scientists to avoid this waste. When coal was burned to make the more concentrated fuel "coke" in the so-called "beehive oven" of the past, important by-products, like ammonia, tar, and benzol, went off into the air in the form of gases and were lost. The modern coke oven preserves these hydrocarbons and turns them over to the manufacturer for future use. Our whole domestic and factory system of burning "raw coal" without the conservation of valuable by-products and with the relatively small amount of heat produced is said by engineers to be so wasteful as compared with a proper modern power plant, that it is predicted coal will in the future be burned at certain fixed points and the resulting heat or power will be carried long distances with far greater economy than by our present method. At all events it behooves us at this time, when coal is so much under discussion, to gain and apply what information we can as to our own particular use of coal, as these engineers are studying the greater problems of industry to make greater savings or better use of the power produced.

COMPETING FUELS OF THE PRESENT AND FUTURE

So interesting is the story of another natural fuel found beneath the surface of our Mother Earth that we have told of "Petroleum" in its history and in the methods by which it is obtained in a special chapter immediately following. But of petroleum as a competing fuel we must speak here. The United States is rich in this oil, and in certain sections in the "natural gas," said to be the most perfect fuel in the world, which is associated with it, both being the product of the slow decay of plant and animal life of long ago. Petroleum is valuable not only as a fuel oil but for many products



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LANDING AT THE TOP OF THE SHAFT

of which it is the source, such as kerosene, gasoline, benzine, naptha, lubricating oils, paraffin, and other less familiar substances which are of importance to the chemist. It has come recently into great demand as a fuel oil in our oil-burning ships and power plants as well as for domestic use. The automobile makes heavy demands on this source of supply for running its engines, and the airplane promises to be equally insistent with its claims. So great is the appreciation at this moment of the present and prospective value of petroleum that nations are engaged in a race to obtain special rights and concessions in those regions which are probably rich in it.

OUR NATION RICH IN ITS RESOURCES

The United States is producing from its own fields a goodly proportion of the world's entire supply of petroleum. It mines from one third to one half of the coal of the world — far more than any other one nation, and almost as much as Germany and Great Britain put together. We take a place second to South Africa in the production of gold. Mexico surpasses us in silver, but we mine it in great quantities; we also produce more lead than any other nation, as well as one fourth of all the zinc. About one-half of the iron and one-half of the steel consumed comes from the United States. Half the world's supply of copper also comes from this country — Montana, Michigan, and Arizona providing the greater proportion of it. And the mineral wealth of the United States is steadily increasing in the value of its annual product.

FALLING WATER A SUBSTITUTE FOR COAL

Beyond all these mineral resources stored in the earth is our water power, a natural resource of almost untold value. We have seen how fuel is reckoned in modern industry in terms of the power resulting from its use. In falling water man has a substitute for fuel which if utilized will do much of his work. This water power is particularly useful for the generation of electricity, since hydroelectric electricity is cheaper than that made by coal. With it as a convenient producer of power for local use and with our widely distributed coal and oil fields, it would look as though we were endowed for generations to come with the possibilities for keeping up and increasing our great industrial systems. It is a long day indeed since Queen Elizabeth would have no coal in her palace because of the gas that was given off when it was burned and decreed that only wood should be burned in London during the sessions of Parliament, arguing that the country gentlemen who came into the city were not accustomed to it and it might not be good for their health.

Photo, Ewing Galloway

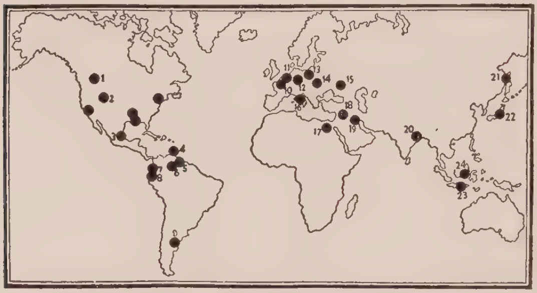
A MOUNTAIN OF COAL IN ALASKA

While the unexplored and undeveloped regions of the earth hold coal supplies like this, we need not be alarmed at the prospect of exhausting the world's coal supply in our time. Alaska has vast mineral wealth

PETROLEUM

WHAT IS PETROLEUM AND WHERE DO WE GET IT?

THE word "Petroleum" comes from the Latin words "petro," rock, and "oleum," oil. Petroleum, therefore, is a mineral oil found in various parts of the world by drilling down through the surface of the earth to the rocks and sands where it lies buried. How it gets there and why we do not know exactly. The United States and the land around the Caspian Sea in Asiatic Russia have produced more oil than any other countries in the world. Men who study the earth and rock formations have told us that there is a great deal of oil in many other places.



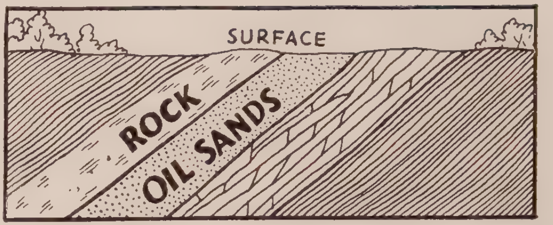
OIL-PRODUCING COUNTRIES OF THE WORLD

1. Canada
2. United States
3. Mexico
4. Trinidad
5. Venezuela
6. Colombia
7. Ecuador
8. Peru
9. Argentina
10. France
11. Germany
12. Czechoslovakia
13. Poland
14. Roumania
15. Russia
16. Italy
17. Egypt
18. Iraq
19. Persia
20. India
21. Sakhalin, Russian
22. Japan and Taiwan
23. Netherland India
24. Sarawak, British Borneo

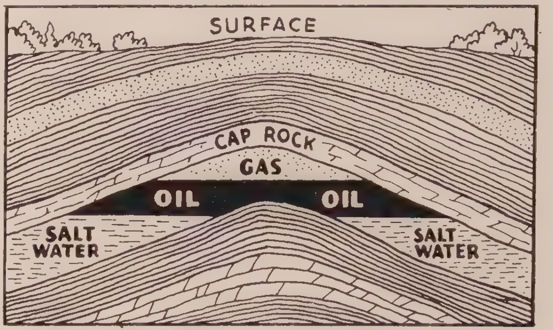
Some of the oil fields of the world have not been opened yet to commerce, but in others modern methods of production and transportation have been introduced which makes them important sources of supply.

The uses of this wonderful "rock-oil," as our great-grandfathers used to call it, were known during the Middle Ages. Marco Polo, the traveler of those times, tells us in his diary that at Baku on the Caspian Sea there were great spouting springs of oil from which shiploads might be taken. He also tells us quaintly: "This oil is not good to use with food but it is good to burn." At a much later period our American Indians found oil of much the same sort in our own country. They used it as medicine. Sometimes they rubbed their bodies with it. They said the oil made them tingle all over and they could run faster.

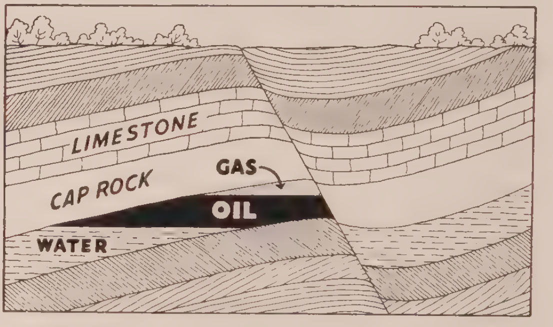
Yet despite many vague tales of the value



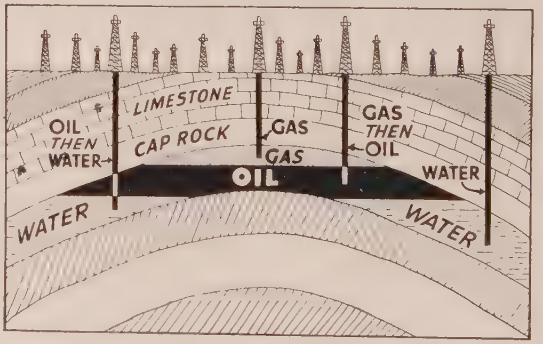
SEEPAGE brings oil to surface when no impervious rock prevents.



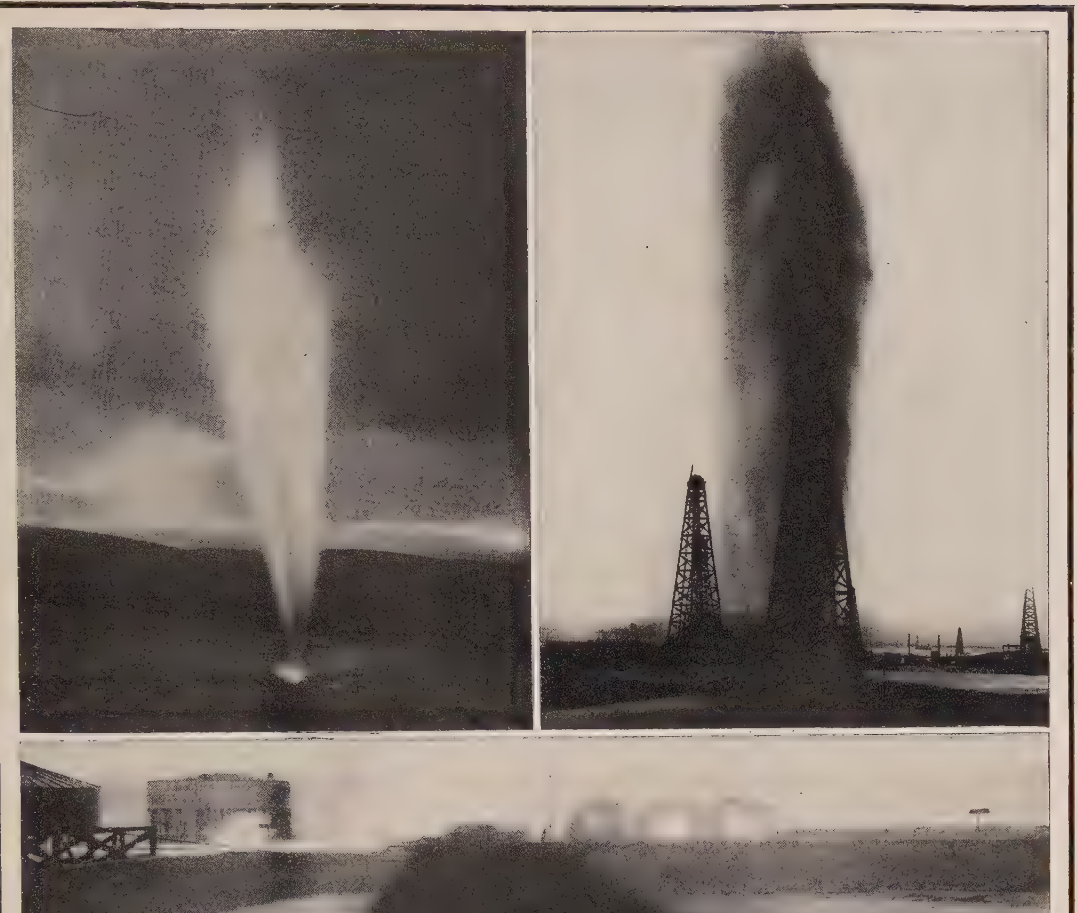
IMPERVIOUS ROCK traps oil in subterranean reservoir. Note relative positions of natural gas, oil, and salt water.



NATURAL ROCK FAULTS, or slips, trap oil below surface.



"OIL IS WHERE YOU FIND IT!" Oil may be found, or missed, although wells be drilled in same field.

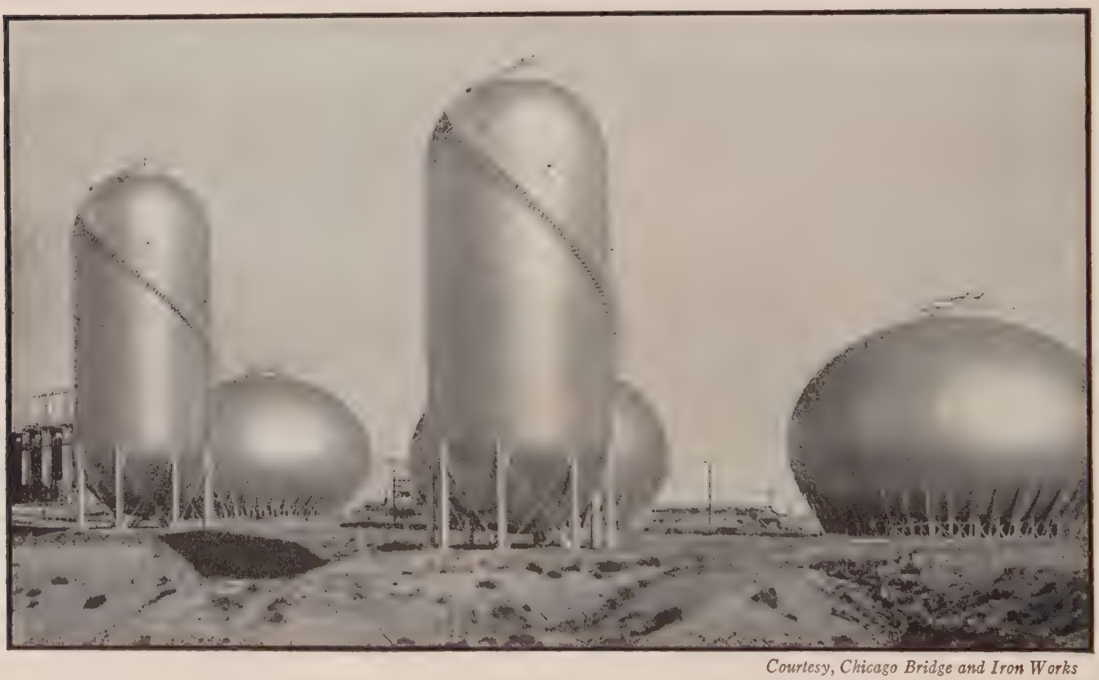


Courtesy, California Oil World

TOP, LEFT: A BURNING "GASSER." A GASSER IS AN OIL WELL CARRYING GAS IN ITS UPPER STRATA. TOP, RIGHT: WILD GUSHER. THIS IS AN OIL WELL NOT YET UNDER CONTROL. BOTTOM: OIL FLOWING WITH TREMENDOUS FORCE INTO A RESERVOIR THROUGH PIPE LEADING FROM AN OIL WELL

AN OIL REFINERY

of petroleum, it was little used. One reason was because people did not know how to get it or what to do with it. Early American settlers used sometimes to put blankets on the ground where oil was and let the thick wool absorb the liquid. Then they would wring it out. Others skimmed oil from the top of springs. None of these people, however, got very much, as you may imagine, and it was not used for burning as is our present-day kerosene, but was used instead as a lotion to be applied as a cure for rheumatism.



Courtesy, Chicago Bridge and Iron Works

STORAGE TANKS

In West Virginia, to be sure, men who were boring for salt in 1806 found petroleum, and in 1848 a man by the name of Kier even distilled some of it and made an oil which could be burned in a lamp, but it smelled so bad and was so expensive that nobody wanted it. A few wells were sunk, but aside from its use for oiling machinery the new product was not taken up commercially. Still there were possibilities in this rock-oil, or petroleum, as it was called. In 1854, Dr. Abraham Gesner got from coal an oil that he called kerosene, and he formed a company which manufactured it successfully. People bought it. They began to use it. The demand became greater. Dr. Silliman of Yale, who had been employed to experiment both with coal-oil and with petroleum, now reported that petroleum could be distilled into a most satisfactory oil for burning.

DRAKE'S GREAT ADVENTURE

In 1859 Colonel Drake was put in charge of a plan to bore for oil at Titusville, Pennsylvania. It seemed a wild scheme. Boring into solid rock was not only difficult but expensive. Workmen drilled patiently, gaining but about three feet a day. No one was sure oil was there anyway. The money for the undertaking was quickly spent and still no oil was found. It began to look as if the entire venture must be abandoned. But Colonel Drake's heart was in his work. He was determined to succeed. He used up his own capital and borrowed more. Then on Saturday, August 27, 1859, the drill ceased to meet resistance and moved in the rock clear and free. The next morning, when one of the workmen visited the works, he found the well nearly full of oil. He could scarcely wait until the next day to attach a pump and force from the earth the two barrels of precious oil. Daily the well continued to yield a constant two barrels.

Then came our Civil War. Money was scarce and people's minds too distracted by the great conflict for them to think of anything else. Oil wells seemed of little importance at such a crisis. But no sooner was peace declared than their attention returned to the getting of oil.

With a rush the land about Titusville was bought up. Towns sprang into being. Many a person who risked all his fortune in the oil country became rich. It was a stampede such as the Forty-niners made when gold was discovered in California and Alaska. Men sank oil wells everywhere. Now Colonel Drake's well, as it happened, was not a large one, and its yield soon became smaller. So certain had the Colonel been that it would be lasting that amid all the excitement he had not bought up other land, and so when his well began to fail, his fortune was lost and he became very poor.

There were in America, however, many men who had become rich through Drake's discovery and they were far too generous to stand by and see the man to whom they owed all their prosperity suffer. Among themselves they raised for him a sufficient sum of money to make him comfortable, and to this the legislature of Pennsylvania added a pension of $1,500 a year so long as either the Colonel or his wife should live.

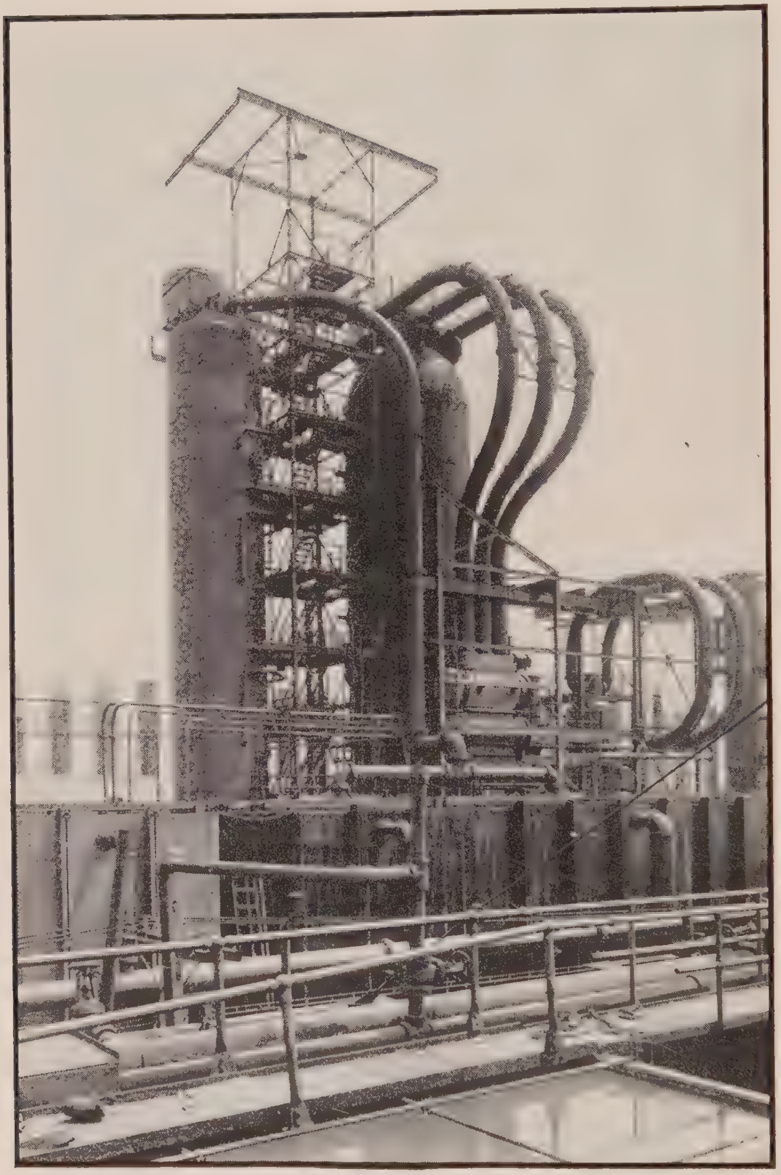
EARLY STRUGGLES IN THE OIL COUNTRY

In the meantime the excitement of searching for oil continued. New country hitherto unsettled and considered valueless was opened up. Men tested for oil, bought land on the chance of making their fortunes, and put their every cent into boring into the rock. Some of these men were successful, and their oil works became centers for towns that either lived until the oil supply was exhausted or grew into prosperous cities; other prospectors were unlucky, and the money put into drilling into the rocky land was indeed sunk in the earth. No oil was found and the once hopeful fortune-hunters faced poverty and despair.

In West Virginia, Ohio, Indiana, California, and Texas, as well as in Pennsylvania, much oil was found, although its quality varied greatly. That which was thick like molasses was used for lubricating machinery. Other oils were separated into their various parts and used for different purposes.

During all these early days of the manufacture of oil, proper care was not taken in distilling it, and there were, in consequence, many disasters. Sometimes a match thrown carelessly on the oil-soaked ground caused fire;

sometimes the tanks ignited, or were struck by lightning and exploded. Yet all the time on went the march of progress. Manufacturers labored to lessen accidents and to perfect methods. Often the wells were clogged by paraffin, and it was at last discovered that by using nitroglycerine, a powerful explosive, they could be cleared and made to yield a far greater supply. Even to-day this method of freeing wells is followed. The explosive is let down, and a cap of powder put on top of it; then a heavy weight is dropped, and with a bang the deep-lying rock is blown to pieces and the oil passage left open.



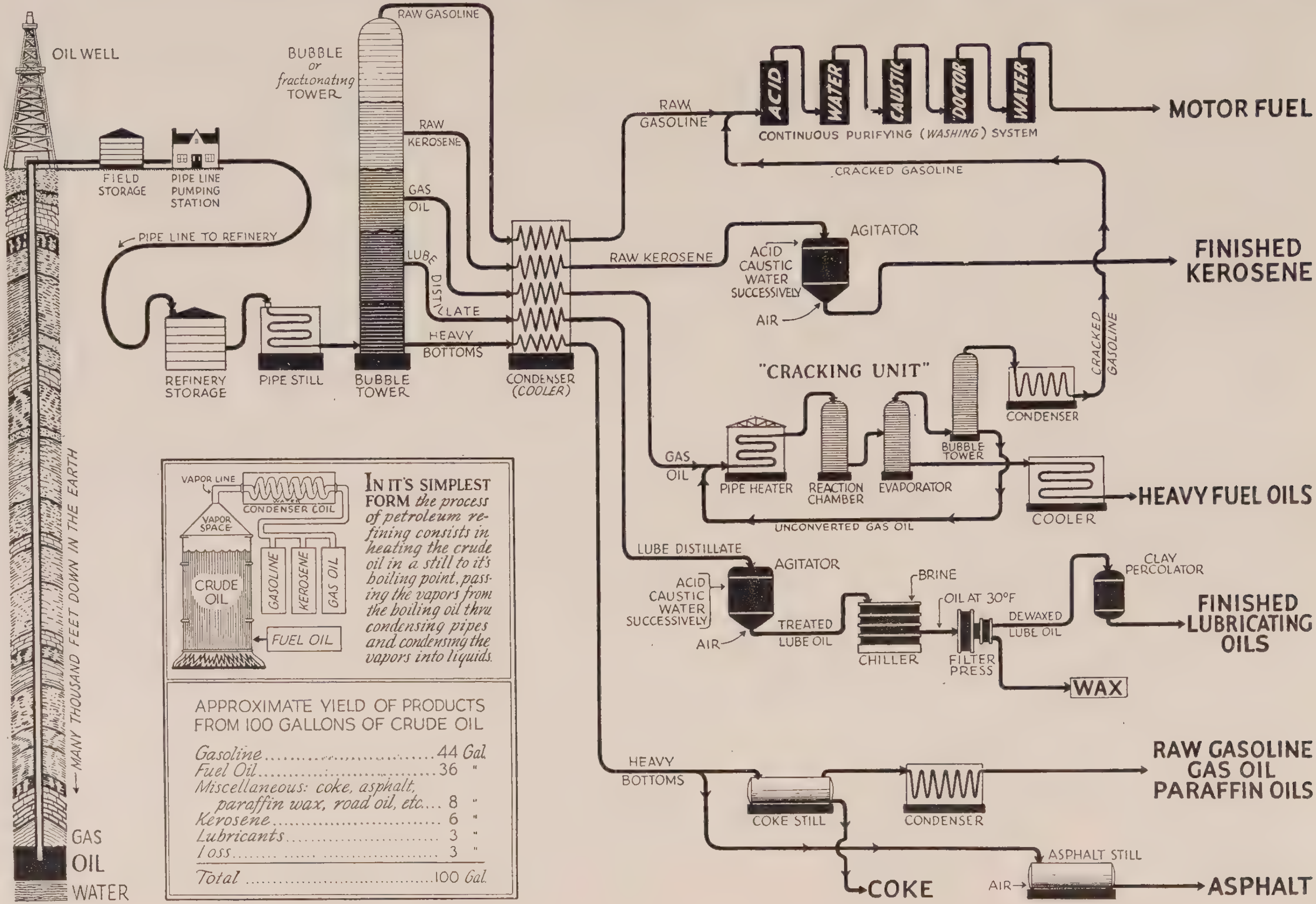
A PETROLEUM STILL

THE PUZZLE OF TRANSPORTING OIL

The greatest problem encountered, however, in manufacturing oil was the expense in transporting the product to centers from which it could readily be sold. Cans and vast tank cars carried the oil miles across the country, to be sure, but as the oil region was rough and difficult to reach, and the distances very great, the profits of manufacture were mostly eaten up by bills for shipping. What was to be done? Here again man's ingenuity came to his aid. Why not run the oil to market in pipes? Why not have miles and miles of pipes reaching from the oil country to the heart of distant cities? It seemed an impossible thing. How was it to be done? The great plan was worked amid the hubbub and opposition of angry transportation companies whose work and consequent profit was now wrested from them. In their rage, men tore up the pipes as fast as they were laid. But in time peace prevailed, and at the present day more than one hundred thousand miles of pipes carry oil to seaport refineries and to cities near the coast. New York, Philadel-

Typical FLOW CHART *tracing* crude oil *from well to finished product.*

DRAWN BY A. M. SINGLETON. NEW YORK. 1934



IN IT'S SIMPLEST FORM *the process of petroleum refining consists in heating the crude oil in a still to it's boiling point, passing the vapors from the boiling oil thru condensing pipes and condensing the vapors into liquids.*

APPROXIMATE YIELD OF PRODUCTS FROM 100 GALLONS OF CRUDE OIL

Gasoline	44 *Gal.*
Fuel Oil	36 "
Miscellaneous: coke, asphalt, paraffin wax, road oil, etc.	8 "
Kerosene	6 "
Lubricants	3 "
Loss	3 "
Total	100 *Gal.*

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American Petroleum Institute

phia, Baltimore, Cleveland, and other large centers are supplied. By means of powerful pumps, the oil is forced on, and when paraffin collects in the pipes and blocks them, as it often does, a tiny machine called a "go-devil" is put inside the pipe and scrapes away the grease with little revolving knives.

WHAT HAPPENS TO CRUDE OIL

At the refineries, the crude oil is pumped from storage tanks into huge stills, where its temperature is slowly raised by the application of heat. Petroleum is made up of a number of compounds, each having a different boiling point. As the heat grows more intense, these elements come off the top of the still in vapors. One by one these vapors pass out through discharge pipes. The first vapor that comes out through the pipe is gasoline, which together with naphtha is the lightest or most volatile part of the oil. Then at higher temperatures we get kerosene, light fuel oil and lubricating oils and other products. After that wax coke or asphalt are left, according to the kind of crude oil that was placed in the still.

The first vapor, which we call "gasoline" because that is what it finally becomes before it has left the refinery, goes through coils of pipe submerged in cold water, where it is condensed into a fluid, and is then stored in other tanks to await further refining.

Kerosene, the next product to be given off, is re-distilled and treated with chemicals to prepare it for burning. Next comes the light fuel oil used to heat our homes; the heavier part of the fuel oil is used to heat big buildings and to feed the great boilers in factories and ocean liners. Further treatment of the next compound gives automobile and light lubricating oils.

GASOLINE AND ITS USES

In the early days, the naphtha and gasoline which came from the distilling process had no value. Disposal of waste gasoline was a problem, as it was dangerous and caused frequent fires at the refineries. The development of the internal-combustion engine changed all this, and has made the gasoline the most valuable of all the petroleum products, although fuel oil is a close second and may equal it in value in the near future.

The gasoline we use in automobiles today is not like the original naphtha and gasoline we saw coming from the still. A number of different kinds of naphthas and gasolines must be blended to form a fuel that will give the best results in the modern motor. Scientific research has brought improved processes of manufacture, all of which lead to the production of greater amounts of gasoline from an equal amount of petroleum.

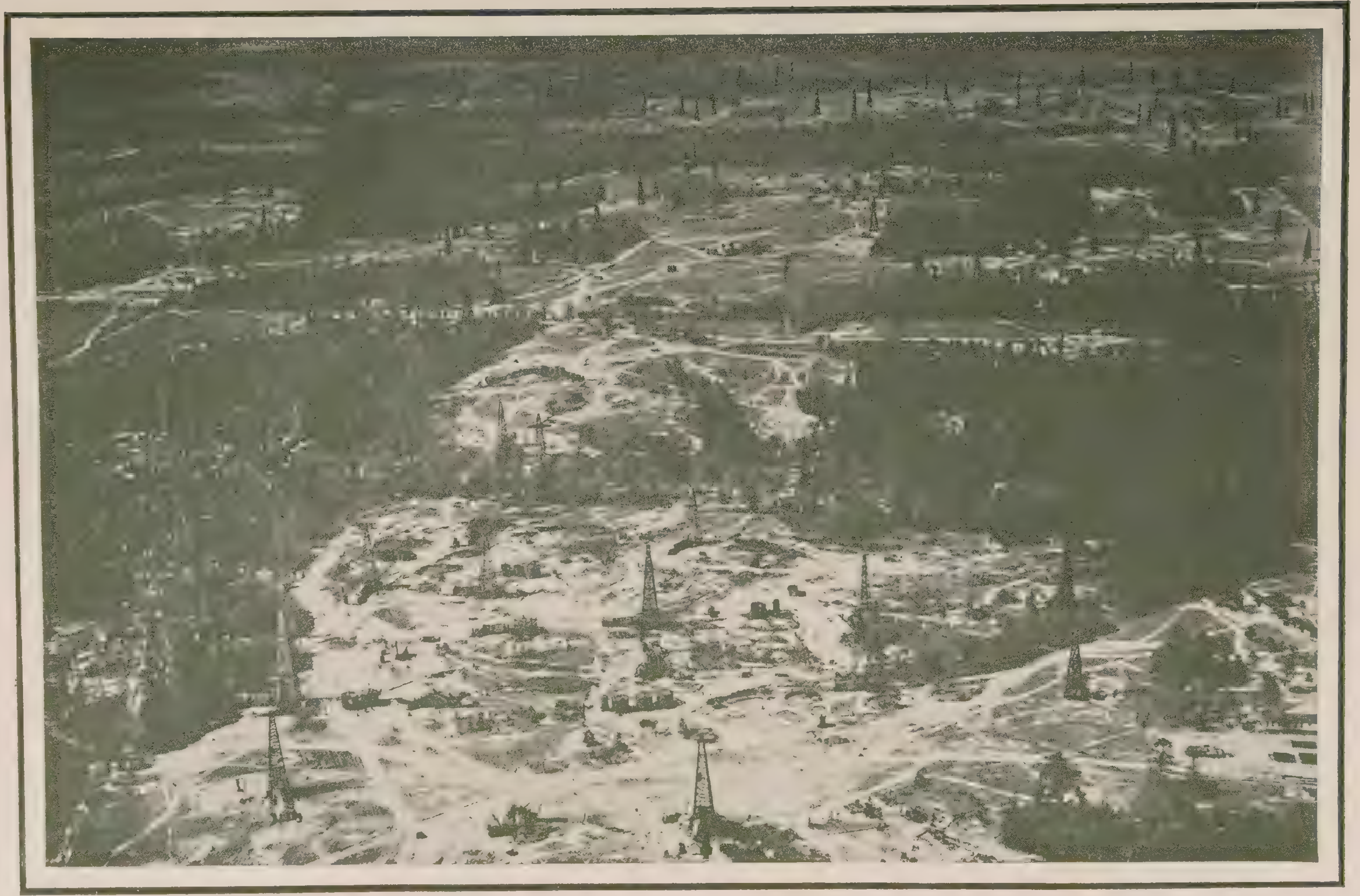
STRANGE USES OF PETROLEUM PRODUCTS

Can you imagine the crude, sticky black oil being transformed into the dyes which color your neckties or dresses, the flavoring of some of your favorite confections, or the perfumes which so delight your senses? The magician's wand of manufacturing chemistry has done all this and more.

Probably no other product enters so universally into our daily lives. Almost everything we touch, eat, wear, or do is affected in some manner by the use of this amazing substance. Authorities say that more than two hundred and fifty commodities contain petroleum in some form or other, and that it has untold possibilities for future discoveries.

It is in rapidly growing use for heating homes, as well as for fuel in countless factories, steamships, and locomotives. Wax, candles, and road oil are some of its better known products. In the cleansing establishments it is used not only to remove dirt from clothing, but in other forms is transformed into the most brilliant of dyes. On our buildings it appears in paint and varnish. Many of the ointments and medicines at the corner drug store base their healing powers on various by-products of petroleum. At the candy store we find it in the flavoring of confections, and in chewing gum. Other parts go into the manufacture of explosives.

It is impossible to list with any degree of completeness the number of ways in which petroleum and its myriad by-products serve us in our everyday existence. Its story is an amazing record of the usefulness of one of nature's greatest gifts to mankind.



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AIRPLANE VIEW OF ONE OF THE LARGEST AMERICAN OIL FIELDS

See how many wells you can count, locating them by their shafts

IRON — THE MASTER METAL

THE importance of any raw product, and of the industries of which it is a basis, can best be estimated if we try to picture a world from which it has been completely and suddenly withdrawn. Without wheat a large part of the civilized world would soon be reduced to starvation; without iron the whole structure of our modern civilization would fall apart and crumble into ruin. It is startling to think how the fabric of our life is built on iron and steel. As we try to picture for a moment what even a shortage of iron production would mean, we find our railroads without rails on which cars could be run, without cars in which to transport men and goods, and without locomotives to pull those cars. We see our factories stripped of their machinery, our homes without their furnaces or stoves, our seas empty of their ships, our means of communication cut off by the absence of all wires, our workmen idle from the loss of their tools.

THE IRON AGE

It is thousands of years since man entered on the Iron Age of civilization, but only in the last century or half century has he learned to handle this metal in such a way as to gain its chief benefits. There was a time, as the arrowheads to be found in many parts of our country show, when man used stone for his tools and weapons. Then on some day, to be written forever as a red-letter day in the calendars of mankind, there flowed from a piece of rock which had fallen accidentally into a hot fire a molten metal. Perhaps iron had flowed out of rock many times before, but this time there was a man watching, a man with a mind to observe and a mind to invent, a man with hands which could fashion the picture in his mind. So before the molten iron from the piece of iron ore had grown cold, he shaped it, and as it hardened, it hardened in the shape of a tool or weapon. The Iron Age had begun. When did this happen? That it was long before the civilization recorded in the historical books of our Old Testament is evident to any reader of these chronicles. If you turn to the book of Numbers, in the chapters of the law concerning murderers (given near the end of the book), you will find that the first weapon suggested as likely to be in the hand of the man of violence is "an instrument of iron"; after it follow suggestions of "a stone in the hand" and "a weapon of wood." Turn a few pages, and in the early chapters of the Book of Deuteronomy you will find set down in the tales of the warfare of Og the king of Bashan the fact that this doughty warrior possessed "a bedstead of iron," and lest we doubt his ownership of so wonderful a treasure, not only its length and breadth are given but also its exact location in a neighboring village or town. Egypt, the land of captivity, is compared on the same page to "an iron furnace," while the land into which the Chosen People were to be led was "a good land, a land of brooks and water, of fountains and springs, flowing forth in valley and hills; *a land of wheat and barley*, . . . a land wherein thou shalt eat *bread without scarceness*, thou shalt not lack anything in it; *a land whose stones are iron*, and out of whose hills thou mayest dig copper." Hundreds upon hundreds of years have passed since those words were written; yet we of to-day might join hands with the ancient Hebrews in thankfulness for a land of wheat and barley, where we may eat bread without scarceness, a land whose stones are of iron and out of whose hills we dig copper.

FROM IRON ORE TO MOLTEN METAL

Iron was smelted by the Egyptians and by the Romans. It was looked upon with high favor by the warlike men of the Middle Ages, whose skill extended to the shaping in their forges of blades of steel. Kipling's old baron voiced the sentiment of many a man of his day when he declared iron to be the master metal. Others had come to him praising different metals.

> "Gold is for the mistress — silver for the maid —
> Copper for the craftsman cunning at his trade."
> "Good!" said the Baron, sitting in his hall,
> "But Iron — Cold Iron — is master of them all!"

"Cold Iron" it is, as man finds it, but not in free or pure form. Iron is said to form one-twentieth of the earth's crust; it exists everywhere in our rocks and soil. But it is only when it is found in rocks (or iron ore) in large quantities that it is possible or profitable to mine it. Here lies one source of our American prosperity, for our country is rich beyond most nations in the possession of this iron ore, and skillful beyond all others in its transformation into steel and the commodities of which steel is a part. The processes by which this rock taken out of the earth is transformed into steel will be described in detail in a later chapter. Here we are concerned not with the technical methods but with the industry as a whole. Before we enter into the story of ways and means it has seemed that we should take two of these basic industries of our nation and look at them in the large, seeing the wonder of what man has done and is doing with these raw materials which he finds in nature. Cold iron it is as man digs it from the earth, cold iron in combination with other substances. But before it can be of use to him it must be handled, as in the days of the Hebrews, the Egyptians, and the Romans, in a furnace. For the melting of this iron ore a vast amount of fuel is required, — two tons of fuel, as it has been estimated, to every ton of iron. Therefore the iron is not smelted in or near its native deposits. From our richest iron ranges near Lake Superior there is in the months of open transportation an unending line of vessels loaded with iron ore, passing through the Soo Canal and down the Great Lakes to ports which are near the great fuel centers of the United States, the coal deposits of Pennsylvania and neighboring states. For the wealth of a nation in iron must be matched by a similar wealth in fuel if the iron is to become valuable to mankind. Into the blast furnaces the iron ore is poured, with the alternate layers of coke or coal to maintain intense heat and of limestone to take up the impurities and hold them in combination until the molten iron has flowed out at the bottom of the furnaces. All that is described in the chapter "From Iron to Steel," page 197.

IRON IN COMBINATION

But what of this steel which we take so for granted in our daily lives, the making of which is a great basic industry in which hundreds and thousands of men are employed? Iron, molten iron or "pig iron," as it comes from the blast furnaces, could not be used in one one-hundredth of the ways in which it is now used. Here the knowledge of the chemist comes in. Iron in this state is ready to combine with other elements. Combined with carbon it forms steel, and the advantage of steel is that it is hard and flexible and strong. The sword makers of the Middle Ages went through the processes of steel making in their primitive form. But it has remained for the ironworkers of the last half of the nineteenth century and of the twentieth century so to manage and control the combination of iron with other elements as to produce a carefully graded series of iron compounds or alloys, each suited to some particular form of commodity.

Pig iron as it comes from the blast furnace is brittle; it is also impure, being not yet rid of all the substances with which it was combined in its original state. It is neither ductile, so that it may be drawn out or worked, nor malleable, so that it may be hammered. But brittle iron is useful for certain products, like the making of stoves. We have therefore blast furnaces turning out "cast iron," which is fusible and brittle. Another kind of commercial iron is "wrought iron," which is so treated as to remove the impurities but to add little carbon. It is a soft and easily worked iron, both malleable and ductile. Steel contains more carbon than wrought iron, less than cast iron. Nor is steel of a given and uniform hardness. Here also there are degrees according to the temperatures at which it is treated or the amounts of other matter added. There is the "soft steel," which is used for boiler plates; the "medium steel," with more carbon, used for building purposes; the "hard steel," used where great strength is required, for axles and shafts, or for tools.

"The value of iron," writes Slosson, "lies in its versatility. It is a dozen metals in one. It can be made hard or soft, brittle or malleable, tough or weak, resistant or flexible, elastic or pliant, magnetic or non-magnetic, more or less conductive to electricity, by slight changes of composition or mere differences of treatment." So the modern worker in iron has learned and is learning to make the combinations as he wants them. He does not confine himself to iron and carbon. Vanadium, tungsten, and dozens of other elements are used as the ingredients of this chemist's brew, and out from them come different kinds of steel, — one for watches and measuring instruments, another for the wires of our electric light bulbs, another for burglar-proof safes, and another for the armor plate of battleships. But underlying all is the basis of the master metal, iron.

IRON AS AN INDUSTRY

Iron is interesting as an industry in itself. From the iron mine to the blast furnace, from which the molten "pig iron" pours out, it gives employment to hundreds of workers. Its transportation is an industry in itself. But iron is most interesting as the basis of many other industries. The steel works of our nation give employment to thousands upon thousands of men. Let there be a labor shortage, or a threat of labor shortage, and the newspapers of the land are found discussing with all seriousness how this great basic industry may be manned so that its output may not be curtailed. Then from the steel works there reach out, like branches spreading from the trunk of a giant tree, the endless varieties of manufactures, small and large, which have for their basis the element steel.

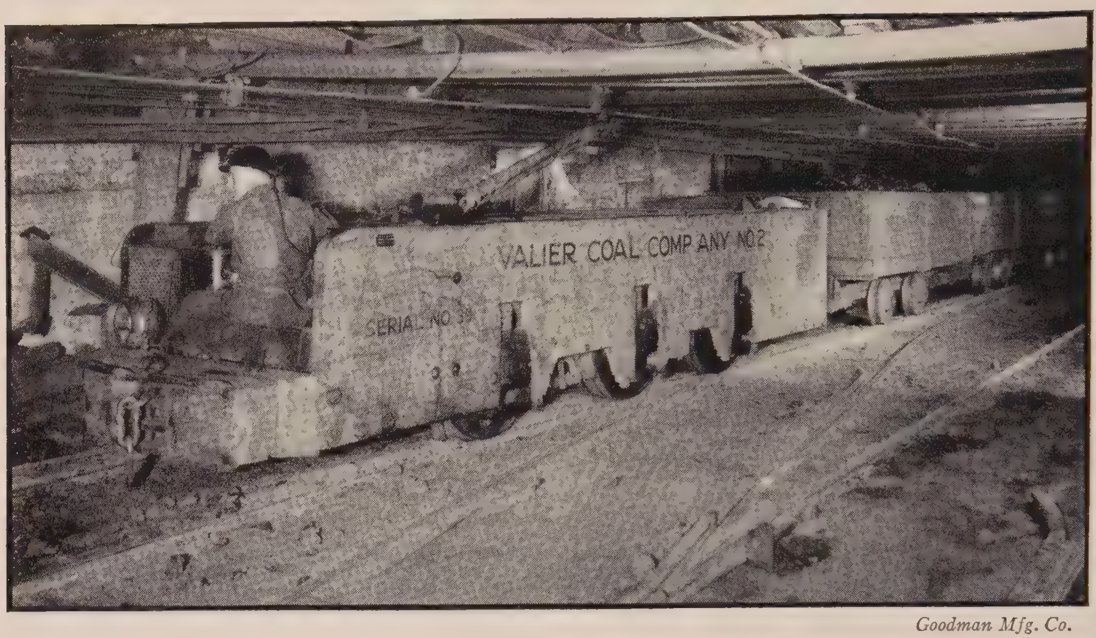
WHAT AN INDUSTRY MEANS TO A NATION

The manufacturing side forms one part of the picture of an industry, the consuming side the other. On the one hand we have the vast army of workers engaged in the production of a raw product and of the finished articles of which it is the basis; on the other hand, the workers of the world — often the very same men and women — who use and depend upon the finished products of the industry. The steel worker is as dependent on steel in his daily life as are the rest of us. He depends also on those who are filling the ranks for the other industries. As the farmer relies on him for his tools and machines, so he looks to the farmer for his food. So from our story of these basic industries we get a knowledge of the importance of the daily activities of the workers of the world, and a sense of their interdependence. Robinson Crusoe on his island had to accomplish the feat of providing for the wants of his life without depending on others. In our modern world every act of our daily life, from the moment when we rise in the morning and eat a breakfast of which the ingredients have come from the ends of the world, until we return from our business and extinguish our lights for the night, involves a background of a thousand workers whom we have never seen and a thousand processes of manufacture of which we know little or nothing. Because of the tremendous interest of this world in the benefits of which we daily share, we are bringing to your attention in this volume some of the industries on which we depend for our daily life. We would have you better acquainted with the fisherman and the farmer, with the miner and the lumberman. We would have you regard the shoes on your feet and the rubber of your automobile tire, the glass and china on your table and the silk, cotton, and woolen with which you are clothed, with a new interest. We would have you know of the food products which come to you from afar; and, while you get a sense of the whole world as ministering to your needs, we would have you become a little more proud and a little more thankful for the wealth of your own native land, which is rich among all the nations of the earth in its natural resources and fortunate above them all in the citizens who make up its great industrial army.

Copyright, Ewing Galloway

SPECIMEN OF ORE

In such form as this is the mineral wealth of our land, in iron, in copper, in silver, unearthed.



Goodman Mfg. Co.

AN ELECTRIC MINE LOCOMOTIVE

THE METHODS OF MINING

SINCE our American way of life depends to such a great extent upon mineral products and since these products form such a large part of the wealth of our country, it should be interesting to know something of the various kinds of mines and how they are worked.

There are several types of mines. Some are merely large holes in the ground where desired mineral has been found at or near the surface and can be dug away with steam shovels. In this class are the "open pit" iron-ore mines of Minnesota and the "strip" mines of the Illinois coal fields.

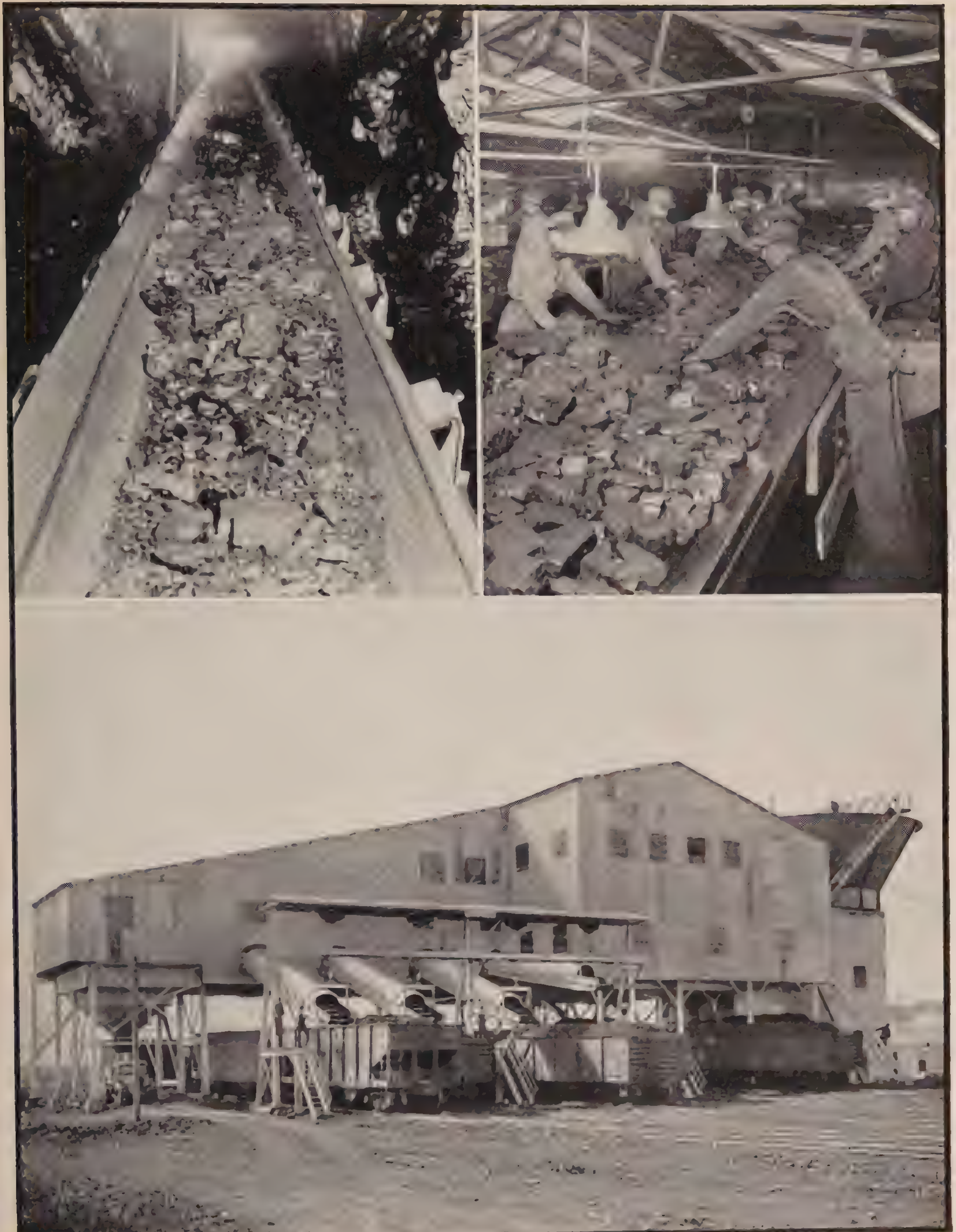
Where the mineral is in veins or beds far from the surface, horizontal tunnels or vertical or inclined shafts are used to reach it. Much of the coal of Pennsylvania and West Virginia is reached by driving tunnels into the hillsides. If possible the tunnels are inclined slightly upward so that water will drain out of the mine naturally and not have to be pumped out. Tunnel mining is cheaper than vertical shaft mining for the loaded cars can run directly to the mine entrance without having to be hoisted up a shaft

Where it is necessary to sink a shaft, horizontal tunnels called "drifts" are dug away from it at various levels to tap the mineral deposit at different places. A large mine may have many miles of tunnels leading away from a single shaft at perhaps a dozen different levels and the main shaft may reach a mile or more into the earth.

One of the problems of mining is proper ventilation and narrow ventilating shafts are some-

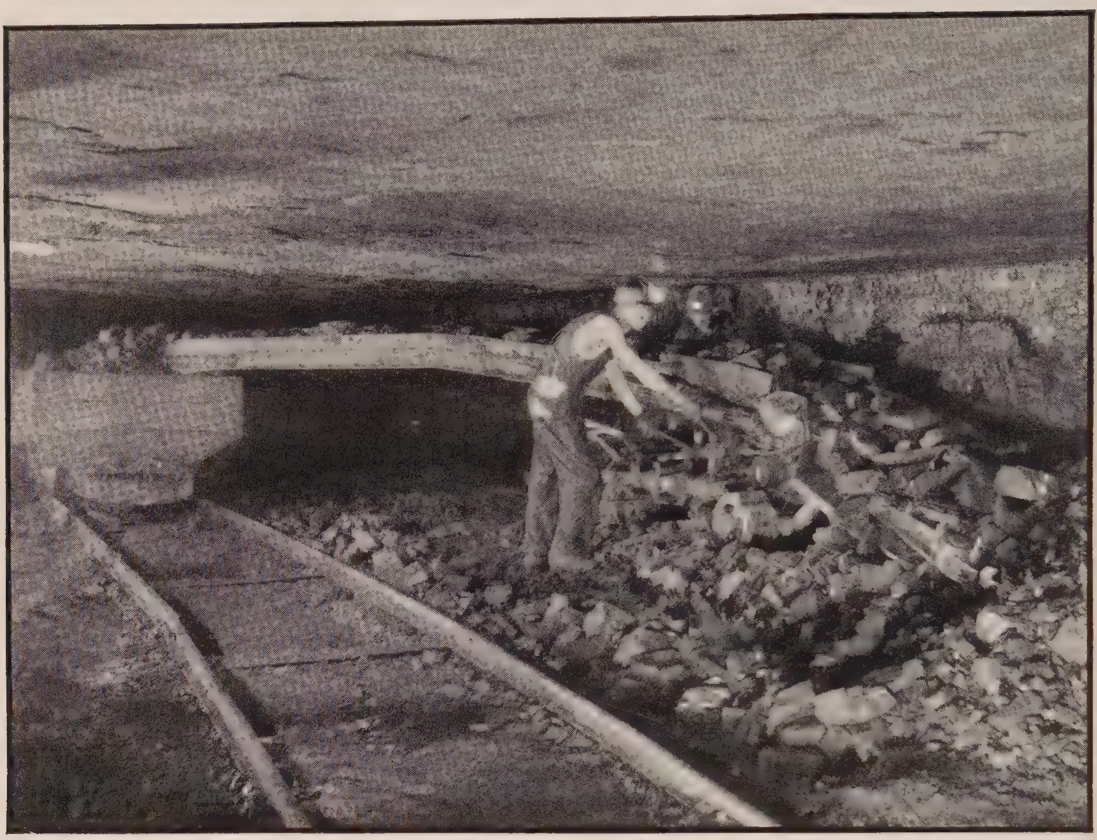
Cleveland Rock Drill Co.

DRILLING HOLES FOR BLASTING



Link-Belt Co.

TOP, LEFT: CONVEYOR BELT BRINGING COAL FROM MINE. TOP, RIGHT: PICKING STONE AND SLATE FROM LUMP COAL AFTER SCREENING. BOTTOM: LOADING GRADED AND CLEANED COAL INTO RAILWAY CARS.



U. S. Bureau of Mines

LOADING MINE CARS BY POWER MACHINERY

times sunk to reach the distant parts of the mine. Today nearly all mines have forced ventilation by means of large blower fans which force fresh air into every part of the mine.

Even with modern power machinery the miner's work is still dirty and there is always some risk of being crushed or imprisoned by cave-ins. And in coal mines there is the dreaded black-damp, a gas which collects in ill-ventilated pockets and will suffocate the miner or explode if brought into contact with fire. Electric lighting reduces the danger of such explosions. Also there is the safety lamp, invented by Sir Humphry Davy, which has its flame screened by wire gauze. The metal gauze permits air to reach the flame but absorbs and carries away the heat of the flame to such an extent that even in the presence of gas the safety lamp will not cause an explosion. In one way the safety lamp is safer than electric light, for in the presence of gas miniature explosions do occur inside the metal screen and thus warn the miner of danger.

In the mining of some metals such as gold and silver, where many tons of ore yield only a few pounds of metal, it is most economical to do the refining right at the mine. The advantage, of course, is that only the metal then needs to be transported. Therefore in many mining regions you will see huge refining mills located at or near the mouths of the mine. In the case of iron-ore, however, the situation is different. The smelting of iron-ore requires great quantities of coke and, in the United States, the largest iron mines are located near the head of Lake Superior far from any coal supply. Hence it is the practice to bring the ore by boat to smelting furnaces located nearer the coal supply as well as nearer the large cities and factories that consume most of the iron and steel.

Courtesy Oliver Iron Mining Co.

AN ELECTRIC SHOVEL DIGGING AND LOADING IRON ORE AT AN OPEN PIT MINE

FROM IRON TO STEEL

FROM the great iron ranges of our Middle West comes more than half of the world's supply of iron ore. Millions of tons of ore are taken from the ground each year to supply the raw material for an industry that provides a livelihood for more than a million people. One great steel company alone gives employment to more than 200,000 men and operates 30,000 railroad cars and 700 locomotives. This will give an idea of the importance of this industry to the commercial welfare of our country.

The mining of iron ore is different from that of coal. Coal is found in an even layer at a certain distance below the ground, and the vein extends over a wide area. Iron ore, on the other hand, is massed in a great body in one place. While this makes it more difficult to locate iron ore by prospecting, it simplifies the problems of mining.

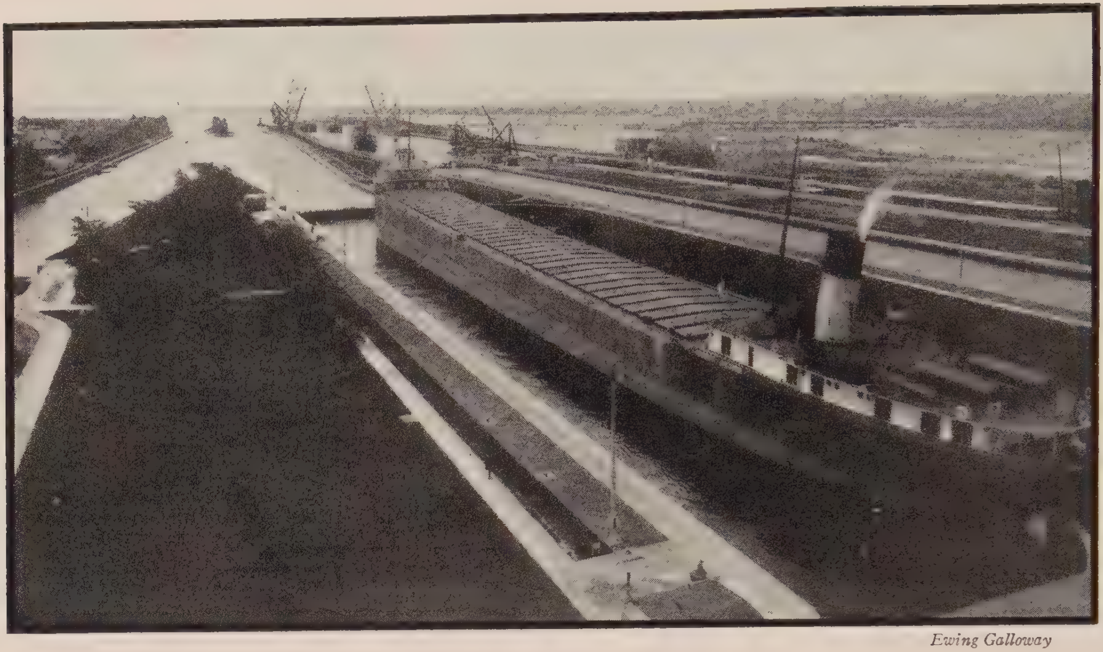
By far the greatest of our iron mining regions is the great Mesabi Range, located in Minnesota to the northwest of Lake Superior. In this region the deposits of iron ore lie near the surface. The surface soil, sometimes sixty or seventy feet in depth, is stripped off until the ore-bearing earth is exposed. This is dug out with huge steam or electric shovels and loaded directly into waiting cars. Such mines are exceedingly valuable because of the ease of mining and the low cost of producing and handling the ore.

FROM MINE TO MILL

The mining and shipping of iron ore is one of the great industries of the Lake Superior region. At the cities of Duluth, Superior and Two Harbors, the ore trains run out on high loading docks and discharge their loads into great storage pockets, built some seventy-five feet above the water. From these pockets the ore slides down through chutes into the holds of the vessels. The ore boats are about six hundred feet long and sixty feet wide and are able to carry from ten to thirteen thousand tons of ore.

Except during the winter when ice makes navigation impossible, the ore boats are constantly at work moving their huge loads of iron ore from the Lake Superior ports through the Soo Canal to receiving docks in the Chicago district or on Lake Erie.

When the ships reach their destinations at the



Ewing Galloway

AN ORE BOAT IN THE LOCKS OF THE SOO CANAL

foot of Lake Michigan or at some Lake Erie port, great hoists and buckets are started on the work of unloading. Here the ore is dumped into cars for transportation to distant furnaces, or is carried to ore piles if it is to be smelted nearby.

STEPS IN THE MAKING OF STEEL

Before the ore can be transformed into the useful steel, it must first be smelted into "pig iron," the name by which the iron is known whether it is in the molten state or has hardened into "pigs," or bars. While we think of iron as a hard metal, it is actually fairly soft. This means that it will not take an edge that can be used for cutting, and will be dented if struck by flint or some really hard substance.

Many years ago it was discovered that iron containing a certain amount of carbon could be hardened by heating it to a cherry-red color and cooling it suddenly by plunging it into oil or water. This is steel, and the hardening process is called "tempering."

The refining of the pig iron transforms the brittle iron into the malleable, ductile (look up these two words in the dictionary) steel that can be hammered, rolled, drawn, stamped, and fashioned into an endless variety of shapes and forms.

AT THE BLAST FURNACE

The first step is at the blast furnace where the pig iron is produced. This furnace may be regarded as a very large stove, seventy-five to a hundred feet high. Into its great mouth are dumped alternate layers of iron ore, limestone, and coke, which become thoroughly mixed in the furnace interior. The coke is ignited and burns with intense heat under the influence of a blast of hot air which is blown into the furnace from below. This melts the ore, and the liquid iron trickles down through the mass and collects at the bottom. The dirt and earthy impurities combine with the limestone to form a light fluid slag, which floats on top of the molten metal and can easily be drawn off. The hot metal itself is tapped into kettles known as "ladles" and is carried in them to the converter, or furnace, where the steel is to be made. All this is hot work, and if you ever visit a blast furnace you will not soon forget it, nor cease to wonder how men can stand the intense heat. When the slag or metal is drawn off it may well remind you of descriptions of the infernal regions.

WHY IS IT CALLED "PIG IRON"?

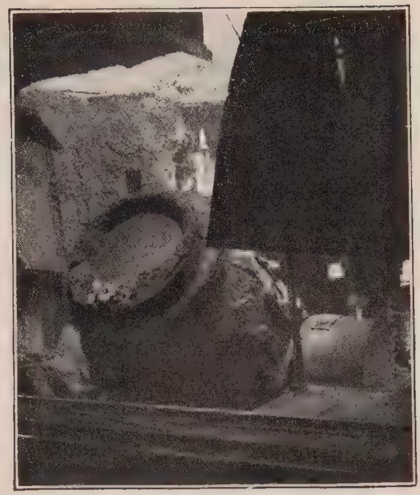
In former days it was the custom to cut ditches in a sand floor, and from the sides of the main ditch smaller ditches, each about two feet long, were dug. The molten iron flowed down the main ditch and into the small ones, where it cooled and was broken up into the bars which all of us have seen. It was because these smaller ditches on each side of the main one looked somewhat like a litter of pigs with their mother that the name "pig iron" arose. To-day the hot metal is carried directly to the furnace to be purified into steel, thus saving the cost of remelting. The blast furnace is tapped five or six times in twenty-four hours, and about eighty tons of molten iron are drawn off each time. A ladle holds from twenty to forty tons of metal.

HOW DO WE GET STEEL FROM PIG IRON?

In this country there are two processes commonly used for transforming pig iron into steel. These are known as the *Bessemer* and the *Open Hearth* methods. Each of these again is divided into two classes, depending on the nature of the impurities to be removed. If there are carbon, silicon, and manganese to be reduced, it is called the "Acid" process. If, in addition to these three, phosphorus and sulphur are present, the process is known as the "Basic." The Bessemer process uses only pig iron as a raw material; in the Open Hearth, both pig iron and scrap (old pieces of wrought iron) may be employed.

In both of these methods the impurities of the pig iron are burned away by bringing air into contact with the molten iron. In the Bessemer process this is done by blowing a blast of air from the bottom through the kettle of molten metal. In the Open Hearth, air passes over the top of the liquid metal, and impurities are either burned or absorbed in the slag. The Bessemer process produces its own heat by the burning of the impurities; the Open Hearth must be kept at the proper temperature by heat from an outside source.

While some manufacturers claim superiority for one method, some for the other, space will permit us to describe very briefly the operation of the Bessemer process alone.



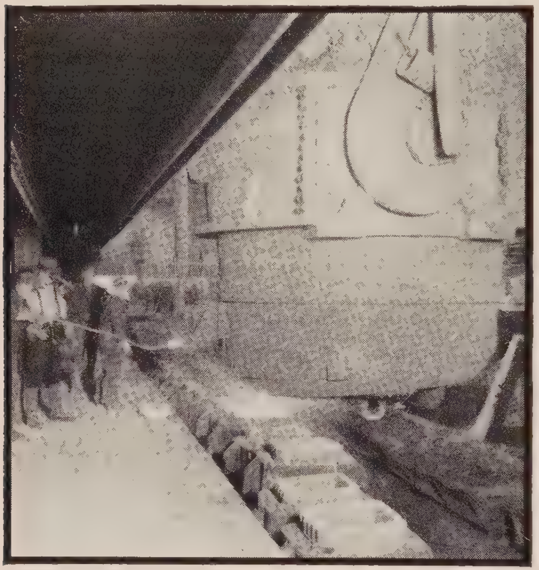
BESSEMER CONVERTER READY TO RECEIVE MOLTEN PIG IRON

WHAT THE BESSEMER CONVERTER DOES

The huge tilting kettle in which the Bessemer process is carried on is called a "converter," because its purpose is to convert iron into steel. In the picture you see the converter tipped over to receive its charge of molten pig iron. As soon as it is charged, a blast of air is started through the bottom of the kettle, which is then turned upright. The air bubbles through the liquid metal just as it would through a glass of water should you blow into it through a straw. The oxygen in this air blast consumes the impurities of the pig iron. The remaining earthy impurities float at the top in the form of slag, while the carbon, silicon, and manganese burn as a gas above the converter, making the beautiful colored flames which illuminate the night when a Bessemer furnace is in operation. The burning impurities keep the bath in a molten state and increase its temperature. When the air blast is first started, immense quantities of black smoke and red flame come out at the top. In twelve or fifteen minutes the metal in the converter is cooked, or purified, the smoke ceases, and the red flame turns to a whiter color. By the color of this flame the expert knows when the charge is ready for pouring.

Of course the finished steel must contain carbon, yet all the carbon in the iron has been burned away. It thus becomes necessary to replace a portion of this material. So, when the flames die down, a small ladle empties into the converter just the quantities of carbon and other substances needed to make the perfect steel.

Now that the operation is completed, the purified steel is poured from the converter into a ladle, which in turn pours it into the ingot molds. The heated ingots, each eighteen inches square and five feet long and weighing about five thousand pounds, go now to the rolling mill. They are ready to be rolled down to smaller size and longer length, for from these ingots come the steel rails for our railroads.



U. S. Steel Corp.

POURING MOLTEN STEEL INTO INGOT MOLDS

At this point the steel may be run through a pair of V-shaped rolls to become an angle iron, or through other suitably shaped rolls to become an I-beam or a railroad rail. When steel is to be used for other manufacturing purposes, the ingots are rolled into "blooms," which are in turn reduced into "billets," or four-foot lengths four inches through.

When in the form of billets, the steel is carried while still red-hot into the yard, where it is dumped for loading into cars. We have now followed the iron ore from the mine to the finished steel in the form ready for various factories to receive it and manufacture it into all kinds of products from needles to massive girders.

SPECIAL STEELS

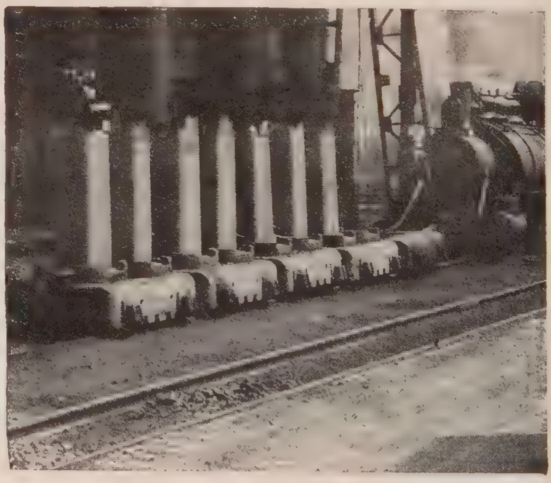
We cannot close this chapter without some mention of the various special steels now so much used in industry.

While a certain proportion of carbon produces steel of intense hardness, there are many new mixtures of iron and other substances, known as "alloys," which have not only the required hardness but other valuable qualities as well.

Iron to which manganese has been added has exactly opposite properties from carbon steel. Dipping heated manganese steel into water makes it less brittle and a little softer. The same is true of steel containing nickel. Manganese steel cannot be magnetized, and is often used instead of copper or brass where a non-magnetic material is required. Again, steel containing certain proportions of manganese and carbon is so hard that it cannot be cut or drilled by tools. This finds use in the construction of burglar-proof safes, and in places where the steel must undergo extremely hard wear.

Manganese, nickel, chrome, tungsten, vanadium, and other substances are among the materials added to steel to make more varied the uses of this most essential of all metals.

Interested readers will find it worth while to supplement this brief story by securing some of the many excellent books on the subject, following the metal iron through its manufacture into pipes, wire, armor plate, tools, and other products.



A TRAIN OF INGOTS

TIN

TIN is not usually considered a precious metal. Yet tin ranked with gold in those early days of exploration when sailors from the Mediterranean Sea were venturing forth into unknown waters for the treasure which they might bring back. The British Isles were sought as the "Tin Isles" before they were ever annexed by Rome for military purposes. The miners of Cornwall were probably bartering their precious metal for bright-colored cloth from the South hundreds of years before Cæsar crossed the English Channel to see what manner of men these unknown Northerners might be. Tin was precious in those days because, by one of the strange freaks of Nature, this soft substance when mixed with another soft metal, copper, made the metal bronze which was harder than either and harder, too, than any other metal known for many centuries. For this reason bronze was in great demand for swords and ploughshares, cooking utensils, and ornaments, and a whole period in the world's history is known as the "Bronze Age." But there could never have been a bronze age without tin.

THE STORY OF THE TIN CAN

We need go back only to the nineteenth century to find a world in which the tin can was not only unknown but most earnestly desired. In 1800 Napoleon and the French Government were offering twelve thousand francs for a method which should preserve foods in wartime.

Over in England a mechanic named Peter Durand was working on tin containers for food. In 1807 he put on exhibition his first tin can, a heavy and clumsy article, but still a tin can. It was patented, and within a few years two American manufacturers learned the art and began to manufacture cans like Durand's in the United States. It was in 1819 that Ezra Dagget and Thomas Kensett began in New York to offer salmon, lobsters, and oysters in tin receptacles, and we may be sure that many a good housewife turned up her nose and spoke with scorn of the idea of eating anything but fish fresh from the sea. The next year two Boston men were canning fruits, and it was in their advertisements, that the "tin cannister" was first announced, the name to be shortened with American speed to the familiar "tin can."

To appreciate what this new invention meant in those days we must go back to Napoleon and his twelve thousand francs, when the preserving of food as we know it was practically undreamt of. François Appert, a French confectioner, was at work on it, and the announcement of the Government prize stirred him to new activity. He had tried many ways of putting away food in glass jars, and finally hit on the idea that if he could completely seal his fruits or vegetables from the air, they came out after weeks or months or years as sweet and unspoiled as they had gone in. It took hundreds of experiments to prove this, but at last he was convinced and was able to convince others. His method was that of all home canning of the present day. He placed his food in containers, covered it with water, sealed and corked it, then placed the container in a bath of water which he gradually brought to boiling point. But, familiar as it is to-day, it was the newest word of science in those days, and for it the Government gladly gave its prize of twelve thousand francs.

Appert did not have the tin can for a container. But when his method became known, it was seen that such a can met the mechanical difficulties of managing the necessary tight sealing of the contents of the container. To-day the canning industry is one of the largest businesses in the United States.

The tin can of today uses only a very small amount of tin. The can itself is made of thin sheets of iron or steel over which a still thinner coating of tin is applied. The sheet iron or steel gives the can strength and is also much cheaper than pure tin. However, the coating of tin is necessary to prevent rust. An uncoated can would quickly corrode and its contents would become unfit for use. Tin is not affected by moisture or by the acids present in many fruits and vegetables.

Explorers have been able to make the long journeys to the North and South Poles and still bring back their men in health because they could take with them in cans the necessary variety of food. Also, thanks to the humble tin can, the products of all the lands of the world may be brought to our tables, and seasonal fruits and vegetables may be enjoyed all year long.

Courtesy of International Harvester Co.

WHERE DOES OUR LUMBER COME FROM?[1]

IN the northwestern part of North America and in the northeastern and southern parts of the United States, as well as in the region of the Great Lakes, are mighty forests. White pine fringe the shores of the Lakes, while in the southern states quantities of yellow pine are found. Hardwoods, hickory, oak, and maple grow upon the lower slopes of the Appalachian Mountains and on the adjoining plateaus. The Rocky Mountain district furnishes chiefly bull pine, Engelmann's spruce, Lodgepole pine. From the states of the Pacific coast come redwood and bigwood. Canada is rich in pine, spruce, hemlock, elm, maple, hickory, basswood, and these woods are distributed very generally throughout the country, with the exception of the central prairie region, as far north as Alaska. Central America furnishes us with mahogany, cedar, logwood and Brazil wood. These trees supply us with lumber.

A LUMBER CAMP A BUSY WORLD

A well-conducted lumber camp is a busy world by itself. When a stretch of timber is bought or leased by an individual or company, the first things done are to locate the boundaries, explore the timber, select the best spots for the camps, and direct their building; pick the crews to work; hire horses; make contracts for machinery; and plan how to manage the forest, to get a good annual yield of timber.

CONSERVATION LAWS

Great care should be taken in making these plans. Many of the trees are located on mountain sides where their roots act as soil retainers and prevent landslides. Furthermore they shade the accumulations of snow not only on hillsides but also at the heads of streams, and if this shelter is removed the snows melt quickly, swell the streams, and cause destruction by freshets.

Another thing to be considered is that many trees — like the hemlock, for instance — will grow only in the shade of other trees, and if the large ones are cut off the new growth will not thrive. When timber land is cut clean over it lies useless for many years, as it takes a long time for another crop of trees to grow upon it. Intelligent managers understand that if they cut only a certain percentage of an area each year, or cut only the ripe trees growing in a given area, they will have a good crop of trees each year, for young trees will constantly be maturing. All these laws which govern careful cutting

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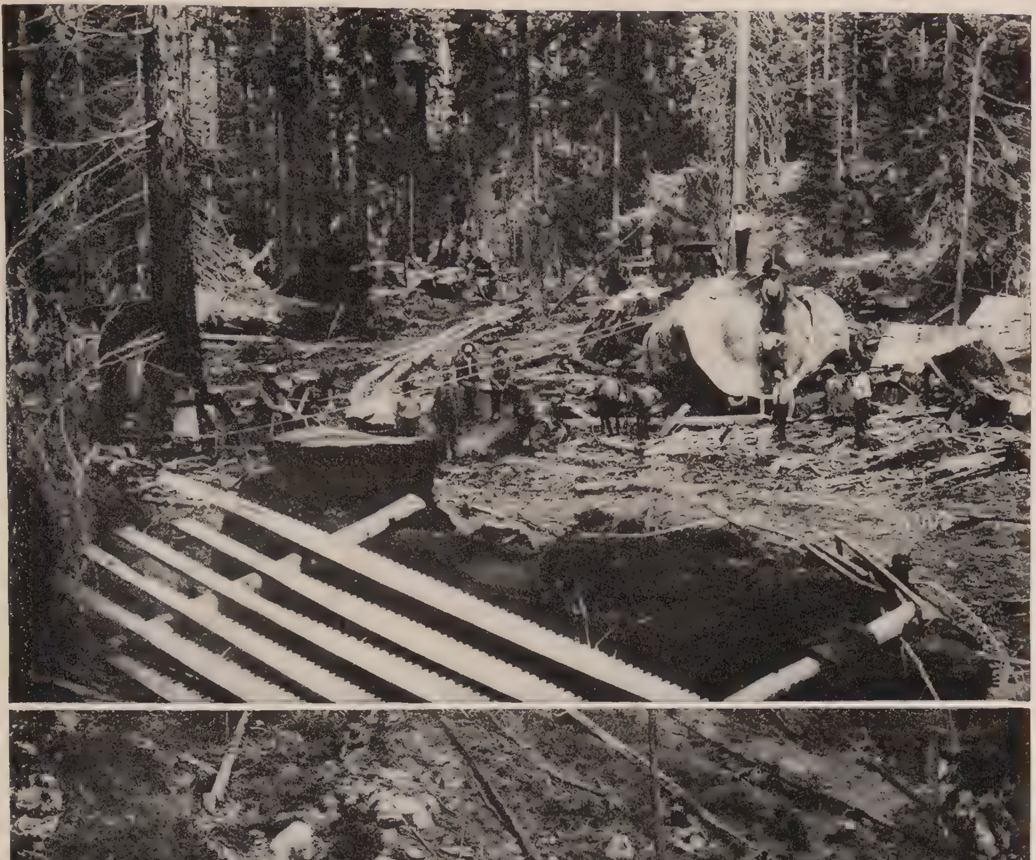
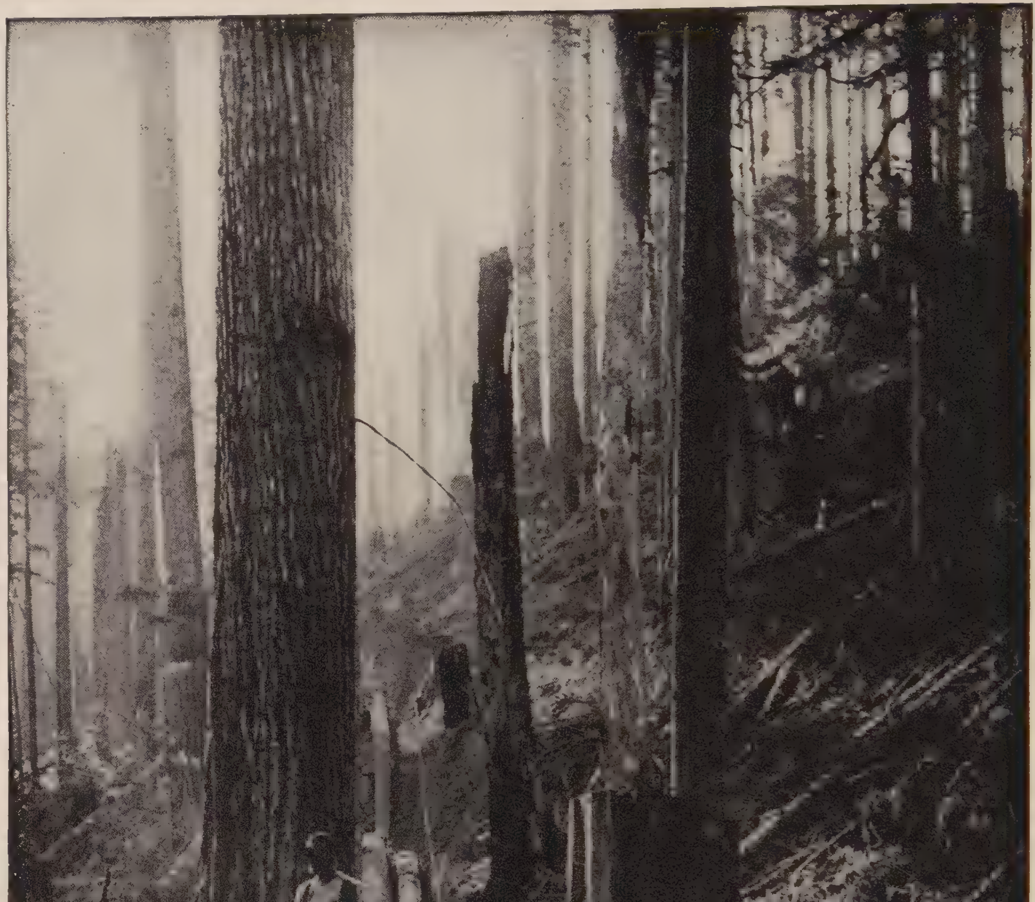
[1] The material for this article is taken from "The Story of Lumber," by Sara Ware Bassett, and is republished through the courtesy of the Penn Publishing Company of Philadelphia.



TOP: ROLLING A LOG ON TO THE TIMBER SLIDE, FRESNO CO., CALIFORNIA. BOTTOM: LOGGING RAILROAD IN A BIG-TREE FOREST, CALIFORNIA



HAULING LOGS BY STEEL CABLE, OREGON NATIONAL FOREST

Copyright, Ewing Galloway, N. Y.

CUTTING A GIANT REDWOOD TREE

and not only foster finer forests but protect the surrounding country, are called Conservation Laws. The United States Government is still busy perfecting these laws, and they should be upheld by everyone who wishes well to our great country. Conservation means guarding what we have that its value may increase rather than diminish.

CAMP LIFE

Throughout the summer the lumbermen are employed in laying corduroy roads and marking the trees that are to be cut. When the snow comes cutting begins.

Roads are broken out and sprinkled each night so they may freeze and keep smooth and icy. When the sprinklers are started on their rounds late in the afternoon, they are filled with hot water, because cold water would congeal before the carts left the camps. Over these ice roads, or skids, heavy logs can be hauled with ease.

Every lumber camp has its blacksmiths, who spend all their time in welding chains for hauling, repairing tools, and mending the runners of sledges. Grindstones, too, whir constantly, sharpening axes and saws. In other sheds and lean-tos carpenters are at work fitting ax-handles of ash to gleaming blades.

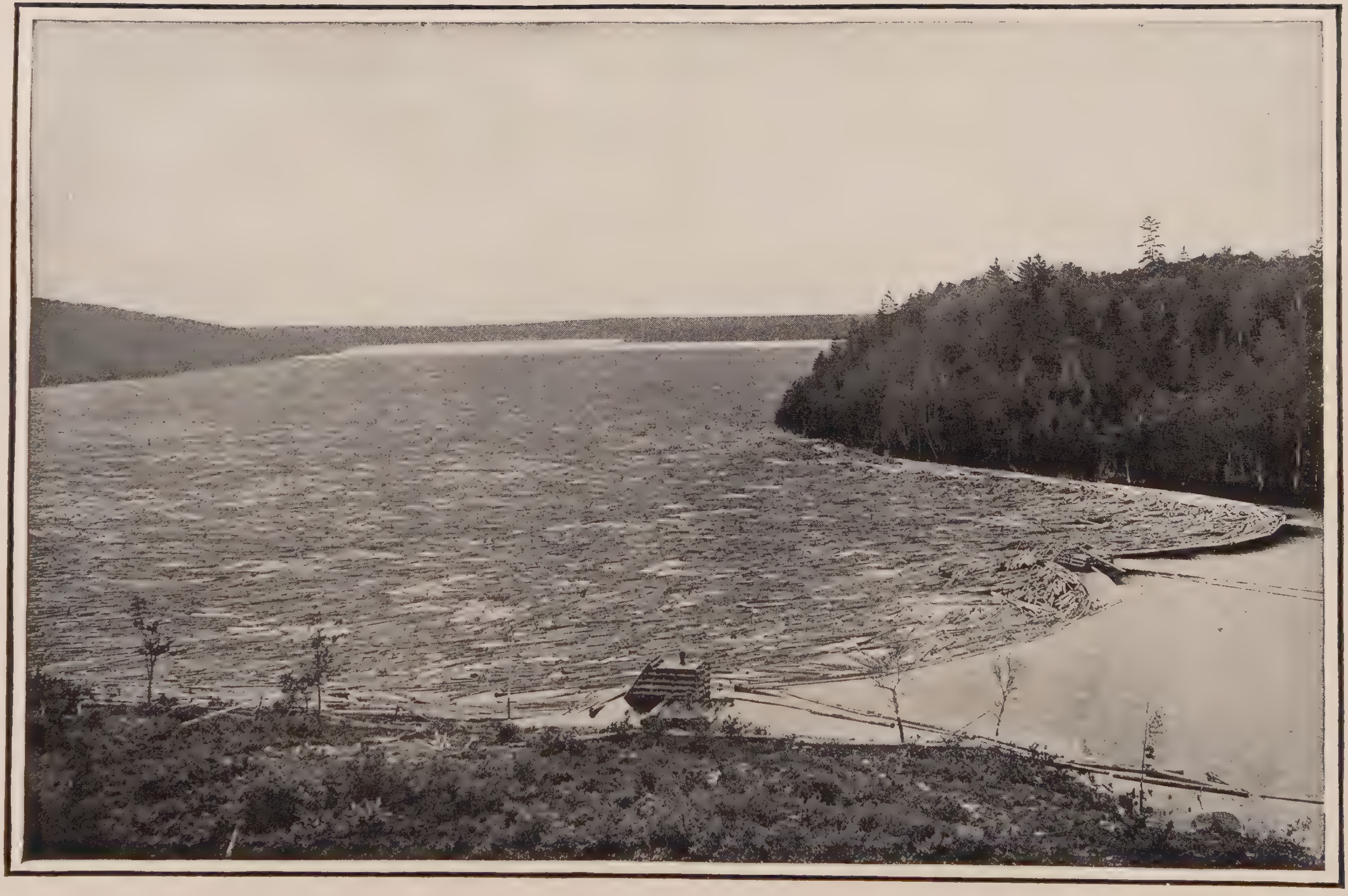
Every tree should be cut so that no stump is more than six inches higher than the tree is wide. This rule prevents waste. The fall of the tree is carefully calculated, so that when it crashes down it may do as little injury as possible to other trees and to the young growth near by. Good lumbermen will quickly release all the saplings that have been pinned down by the weight of falling timber. After the tree has fallen the branches are lopped off and carted away, either to be burned at the camps, to be used as soil retainers in repairing wood roads, or, if they chance to be balsam boughs, to be employed as bedding in the bunks at the camp. If these branches are not carried away a wise manager will insist that shoots on the under side of the branches be cleared off, that the branch may lie flat on the ground. It will thereby rot more quickly and become part of the forest floor. Nothing is more likely to cause forest fires than a litter of dry boughs on the ground.

When the timber is cut and stripped it is then hauled or skidded and piled where men with sledges can readily collect it and carry it to the margin of the lake or river near at hand. If lumber is cut on the shore of a lake a large boom or frame of logs fastened together by chains is made on the ice, and inside this boom the logs are placed. As soon as the ice melts in the spring this boom will drop into the lake and may then be towed across the lake to the dam, or sluice, so that the logs inside it will be ready to be driven downstream.

THE RIVERMEN

The journey of logs down a river to the mills is called a "drive." Log driving is both dangerous and exciting work. The men who drive the logs are called "rivermen." They wear slouch hats which will shade their eyes and at the same time stay firmly on their heads despite the wind. They also wear flannel shirts, trousers cut off at the knee, and long boots. Usually these boots have holes slashed in the toes to let out the water. Rivermen become very skillful in jumping from one slippery log to another; in retaining their balance when the logs move rapidly and crash into other logs; and in running the length of logs even when they are bobbing about in a seething current. Often the rivermen are waist-deep in water from dawn until dusk, for when the drive once starts it must be hurried along before the rivers, high with the spring floods, fall. Sometimes the weather turns cold so that the streams freeze again. Then the rivermen must go ahead and blast out the ice in order to keep the waters open. Frequently they are obliged to work all night to prevent the streams from freezing over.

Being in constant danger makes the rivermen a reckless crew. So often are they thrown into the water that unless they seem in real danger little attention is paid to their plight. They will float downstream clinging to the logs and clamber to their feet, smilingly drying their clothing in the air and sunshine as they continue on their way. An old and tried riverman is proud of his skill, and many a time when in midstream will cut up every sort of foolhardy caper for the delight of his companions.



A LAKE FULL OF LOGS

This vast collection of cut timber conveys a graphic idea of the scale on which lumbering is carried on in some parts of North America.

Copyright, Underwood & Underwood

SAWMILL IN BIG-TREE DISTRICTS, MILLWOOD, CALIFORNIA

The drive begins as early in the spring as the ice is out of the streams and is rushed along as rapidly as possible. The time required is dependent on the distance traveled and on the good luck experienced on the drive. Generally even a long drive will reach the mills by late spring or early summer. Driving crews come into the lumber camps late in the winter and from then on watch eagerly for signs of a thaw. Then the huge piles of logs along the river's edge are tumbled into the stream or "broken out," as it is called, and the sluice-gates at the foot of the lakes are lifted so that logs inside the booms may be turned out and hurried over the falls.

Crews of rivermen go ahead to direct the front of the drive, while others stay at the rear and send the logs along. The rivermen carry long poles having stout iron hooks in the end; these they use not only to urge the logs onward but also to help them to keep their balance. These poles are called "pick-poles" or "peaveys." Without them it would be impossible to keep the logs moving along in the current of the stream.

A JAM

One of the disasters a riverman most dreads is to have a block in the logs. This is called a "jam." Sometimes a log will become lodged upon a boulder or other obstruction, and before it can be freed other logs will pile up against it. The pile increases rapidly. Then the river crews must exert all their prowess to clear the jam. Not infrequently this can be done by finding the "key log" and dragging it out, thus loosening the entire heap. It takes the most courageous men to pick a jam in this way, for the moment the pile is free it sweeps down the river, often taking the rivermen along with it. When such dangerous work is necessary, the men are never compelled to do it. The man directing the work always calls for volunteers. Strangely enough more men usually beg to go than are needed. When it is impossible to free the jam, dynamite is used to blast it out.

After the logs reach their destination they are hauled on moving platforms into the sawmills along the shore and first stripped of bark. This bark is dried, packed, and shipped to tanneries. The slabs, or curved faces of the logs, are then cut off and utilized for shingles or laths. The slabs off, the square bolts of wood remaining are run into machines which grip them firmly and cut them into boards by means of bandsaws. Sometimes circular saws are used, but as these make a wider kerf or "bite," and are therefore more wasteful, the bandsaw is preferred.

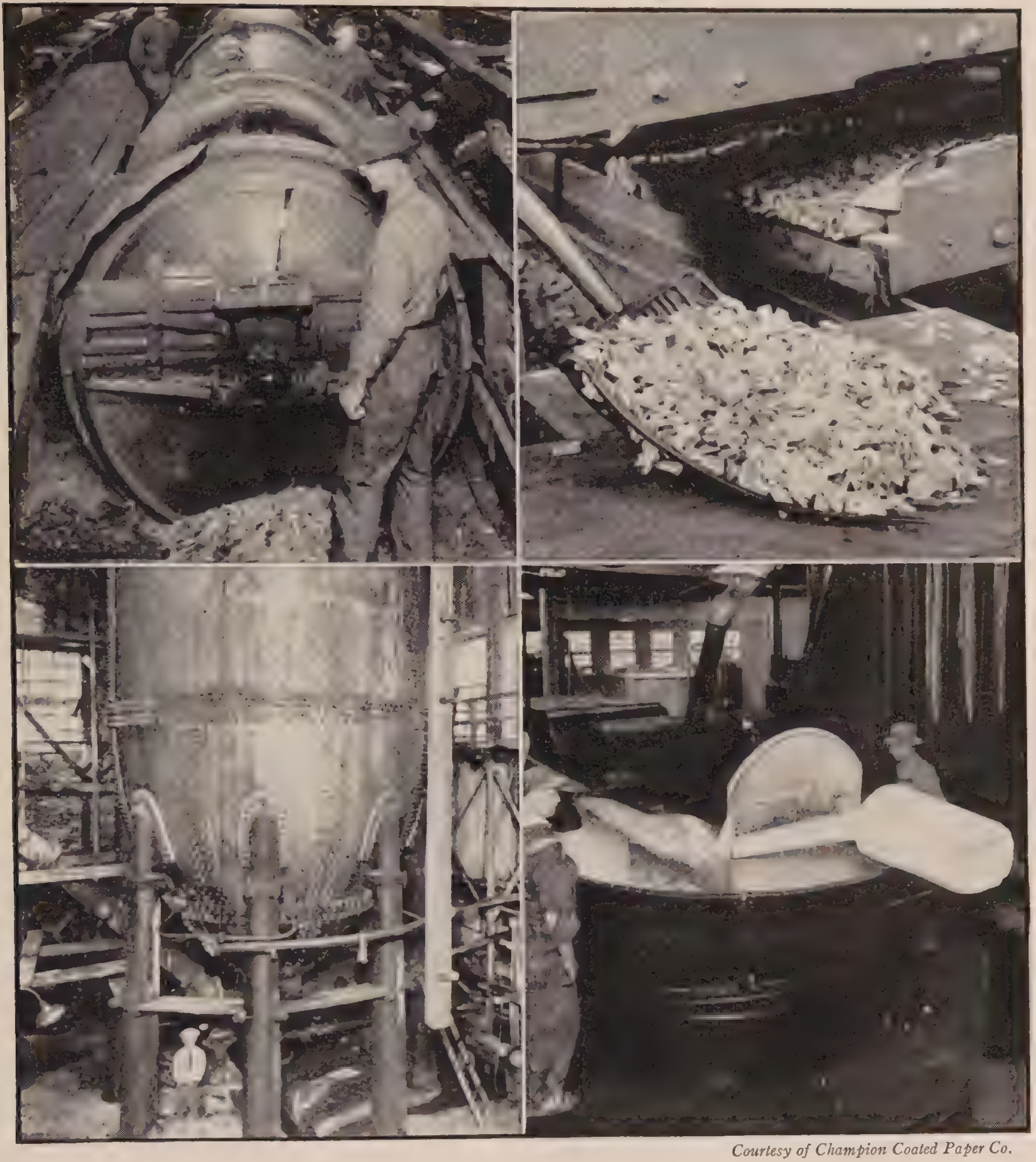
The boards being cut, they are then taken to the lumber yards and piled crisscross in order that the air may find its way between the layers and dry them. This is called "seasoning" the lumber. Some boards are kiln-dried that they may not warp or crack when used in the interiors of buildings. Most lumber mills are so situated that they have easy access to railways or ships, by which their products are transported.

PAPER

THERE is scarcely a commodity of present-day civilization that answers so many purposes as does paper. Not only have we newspaper, wrapping-paper, books, and stationery, but we also have paper turned to scores of amazing ends, such as plates, towels, napkins, drinking cups, combs, and even locomotive wheels. Then, in addition, there are the multicolored tissue papers of every conceivable shade and design.

ORIGIN IN CHINA AND HOW IT BECAME KNOWN TO EUROPE

It is interesting to look backward to the days when the Babylonians wrote in hieroglyphics on brick, or the Egyptians scratched their messages on the ancient papyrus, the first primitive paper made from the pulp of the papyrus plant. Then came centuries when the Chinese and Japanese were the only paper-makers in the world, and when no one else knew there was such a thing until an Arab adventurer strayed into China and brought back the secret to the Moslem empire. It was a great discovery to the Arabs, who were scholars as well as warriors, and anxious to spread their religion throughout the world. For a long time, between the eighth and ninth centuries, Damascus was the great paper-making center. Then the Moors usurped the trade and kept

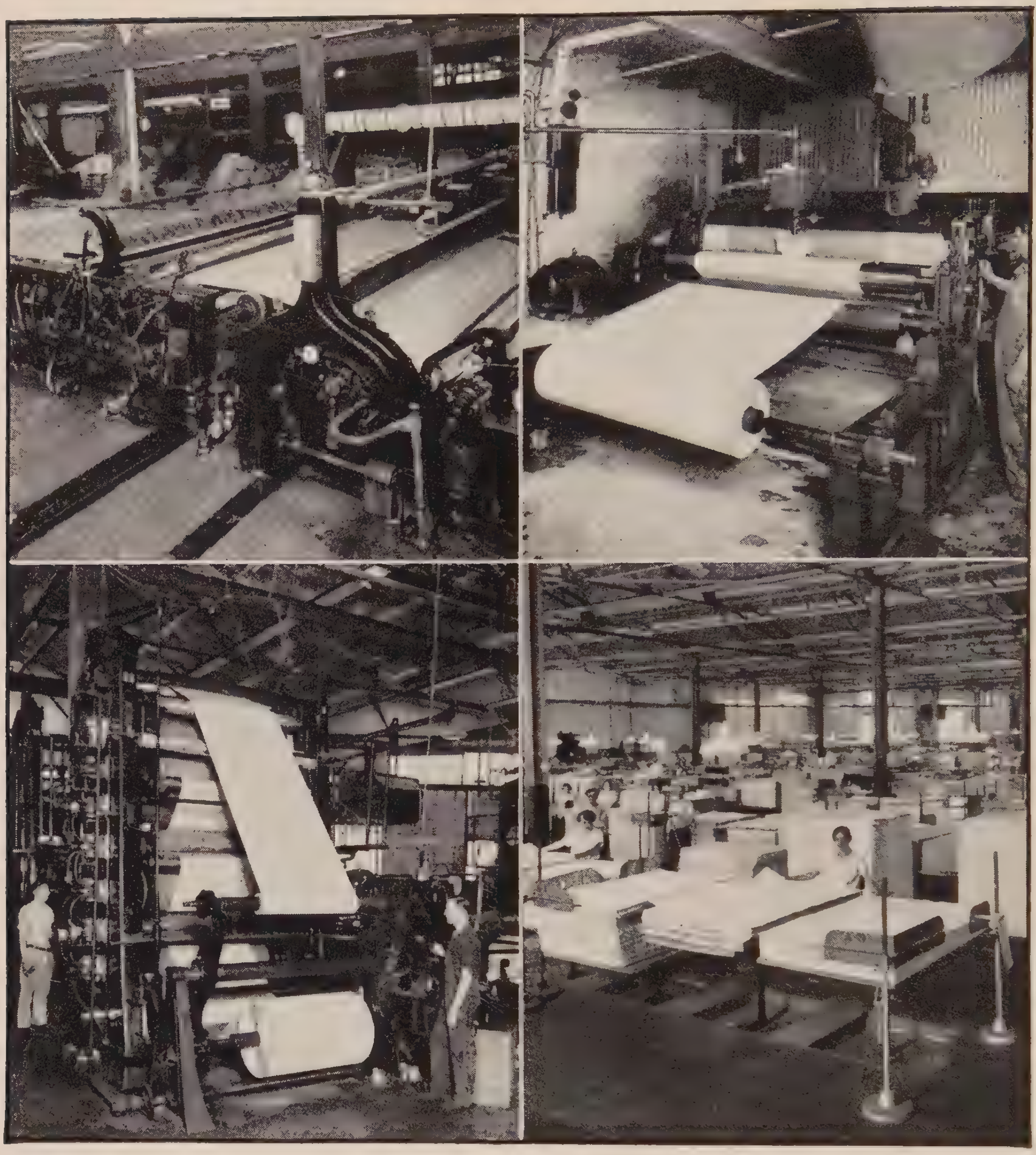


Courtesy of Champion Coated Paper Co.

MAKING PAPER FROM WOOD. UPPER LEFT: CHIPPING MACHINES WHICH CUT CORD WOOD INTO FLAKE-LIKE CHIPS. UPPER RIGHT: THE CHIPS. LOWER LEFT: DIGESTER TANK IN WHICH THE CHIPS ARE TREATED CHEMICALLY TO LOOSEN THE WOOD FIBERS. LOWER RIGHT: BEATING ENGINE WHICH MIXES WOOD PULP WITH WATER.

it until they were driven out of Spain and the industry was swallowed up by the Spaniards. At first the Spaniards had no great luck with the new product, and while they were struggling with it the French mastered it, and about the thirteenth century took the first place at paper-making. Holland followed; and later, England, through her close contact with the Dutch, learned the art. Lastly America entered the field and at the present time is the greatest paper-making nation of the world.

The revolution caused when paper was first



Courtesy of Champion Coated Paper Co.

MAKING PAPER FROM WOOD. UPPER LEFT: PAPER MAKING MACHINE WHICH RECEIVES PULP FROM BEATING ENGINE. UPPER RIGHT: COATING MACHINE. LOWER LEFT: CALENDERING MACHINE. LOWER RIGHT: SORTING ROOM.

made can hardly be realized by one living in our day. At that time the masses of people were uneducated. There were no newspapers, and few books. What books there were were laboriously written by scholars or monks on bleached skins, or parchment, and illuminated by hand. An occasional traveler, or the minstrels who journeyed through the countryside or wandered from one castle to another, brought the news from the outer world; history and literature took the form of ballads which were chanted to the music of the harp. The minstrel, as you may well imagine, was welcome wherever he went; he was both the newspaper and the book of the day. People then liked stories quite as well as we like them now — perhaps even better; and since they had so few opportunities to gratify this craving they not only listened eagerly to the ballad singers but they painted all sorts of tales into their pictures and church windows, and wove stories of battle and adventure into their tapestries. Then hand in hand came the making of paper and the invention of printing (see "Inventions"); and the learning of the scholar, the lay of the minstrel, became the heritage of the world.

EARLY PAPER-MAKING AND HOW IT HAS IMPROVED

The first paper-making was done in very small quantities and entirely by hand. Manufacturers had not yet found out that it was possible to bleach colored rags with acids, as we do now, and use them for white paper; they thought that to make white paper they must use white rags. Cloth was expensive and so many white rags were hard to collect. In consequence little white paper was to be had. Instead there was a crude yellowish or grayish paper, and even that was costly. The method for making it contained, however, all the essentials of the processes followed to-day. Then, towards the end of the eighteenth century, Louis Robert, a clerk working in a French manufactory, came forward with his paper-making machine, which speedily took the place of hand processes and multiplied many times over the supply of paper that had previously been made. This machine is the basis of the elaborate devices used at present in our factories.

There was now no question of not being able to make enough paper; the sole problem was where to get the large supply of rags demanded. When, towards the middle of the nineteenth century, it was discovered that paper could be made from wood pulp, what a turmoil it caused in the industrial world! The fine grades of paper must still be manufactured from rags, it is true, but the cheaper kinds could be made from the fiber of poplar and spruce. Paper mills were rapidly removed from cities to the banks of streams, which not only provided power for running the machinery but rendered it possible to float logs down the rivers to the very doors of the mills. The most successful method for cutting up wood fiber has proved to be the grindstone. By this means the wood is ground fine and made into the pulp for our cheapest paper. Since, however, there is no long fiber in this pulp, the paper is weak and tears easily; for a stronger and better paper the wood is dissolved in acids, where the long fibers are softened and separated from the valueless part of the material. Often some wood fiber is blended in rag papers. Esparto grass is also dissolved and mixed in for other qualities of paper. The more rags and the less of other fiber, the finer and stronger is the quality of the material made.

Paper of pure new rags is the best we have. Our paper money, and the finest of writing and printing papers are made from new rags to give finer appearance and greater durability.

HOW THE RAGS ARE PREPARED

When bales of rags arrive at the mills they are first put into openers, where they are pulled apart; they then go on to the beating machines, where much of the filth is thrashed out of them, and they are put into more fit condition to handle. Afterward the material is sorted — all buttons, hooks, etc., being taken off, and the rags shredded in small bits; later they are cut still finer by a chopper, and often large magnets are used to extract every remaining particle of metal. Then into great cone-shaped machines lined with spikes go the rags, and here they are torn, beaten, and cleansed, after which they are exposed to powerful blasts of air that blow out all dust and leave them in proper condition to be dissolved into pulp. This is done in giant boilers, where they are mixed with lime and soda and boiled from twelve to fifteen hours. The material is then dark and jellylike and must go into "hollanders," which wash it and at the same time separate the strong, valuable fiber from the soft, mushy part of the mixture. This fiber is drained off and put into beaters that work it into a pulp. Bluing is added to the bleached rags to give them a pure white tone, and sizing put in to give body. Some sizings are poor blends of mineral matter and chemicals, and the resulting papers are cheap and easily torn.

At this stage the pulp looks like a thin flour-paste. It is then poured upon fine wire frames through which the water is drained; the thickness of the paper is regulated by the amount of pulp poured onto the frame, and the width by the edges between which it is confined. The layers of felt, and the heavy cylinders between which it afterward travels, take out the moisture, dry it, and give it its finish. During these various processes it comes in contact with the "dandy roll" — a small, wire-covered cylinder — which leaves upon the paper the imprint woven in the wire. Sometimes this is a textile effect, sometimes the name of the firm manufacturing it; sometimes it is a symbol from which the paper takes its name. Most of the markings indicate the quality of the paper. In handling old and rare manuscripts these watermarks are often of great value in determining the date and genuineness of the curio.

THE MANY KINDS OF PAPER

Ordinary newspaper is made, as has been said, from wood pulp; this is rolled out, and is delivered in rolls to the printer ready for the press. Book paper is "machine finished" — that is, it is in condition to use when taken from the machine. If a polish is demanded it is calendered. Most book paper, however, is without glaze, since for ordinary unillustrated books the glaze is not needed. Coated paper for illustrated magazines and books is brushed over with a coating which is frequently made from English clay and glue. All calendered paper is treated with a white sizing and then passed very quickly over hot rollers. The result is the same as that obtained when starching and ironing cloth — a high gloss is imparted to the material. Writing papers are made from mill ends or linen clippings, and given their various finishes in the "plating" or pressing.

The old newspapers and magazines which you sell to the junk man are put through a chemical process which removes the ink, are turned into pulp, and made again into clean new paper.

Materials such as hemp, jute, and even straw enter into the composition of other kinds of paper, particularly the coarse brown variety used for wrapping.

With the world's supply of pulp wood growing smaller each year before the destructive axe of the lumberman, science is searching eagerly for new materials from which the newsprint paper of the future can be economically made. An entire edition of a farm magazine was recently printed on paper made from cornstalks. It has the appearance of newspaper, but the manufacturing process is still too expensive to be practical.

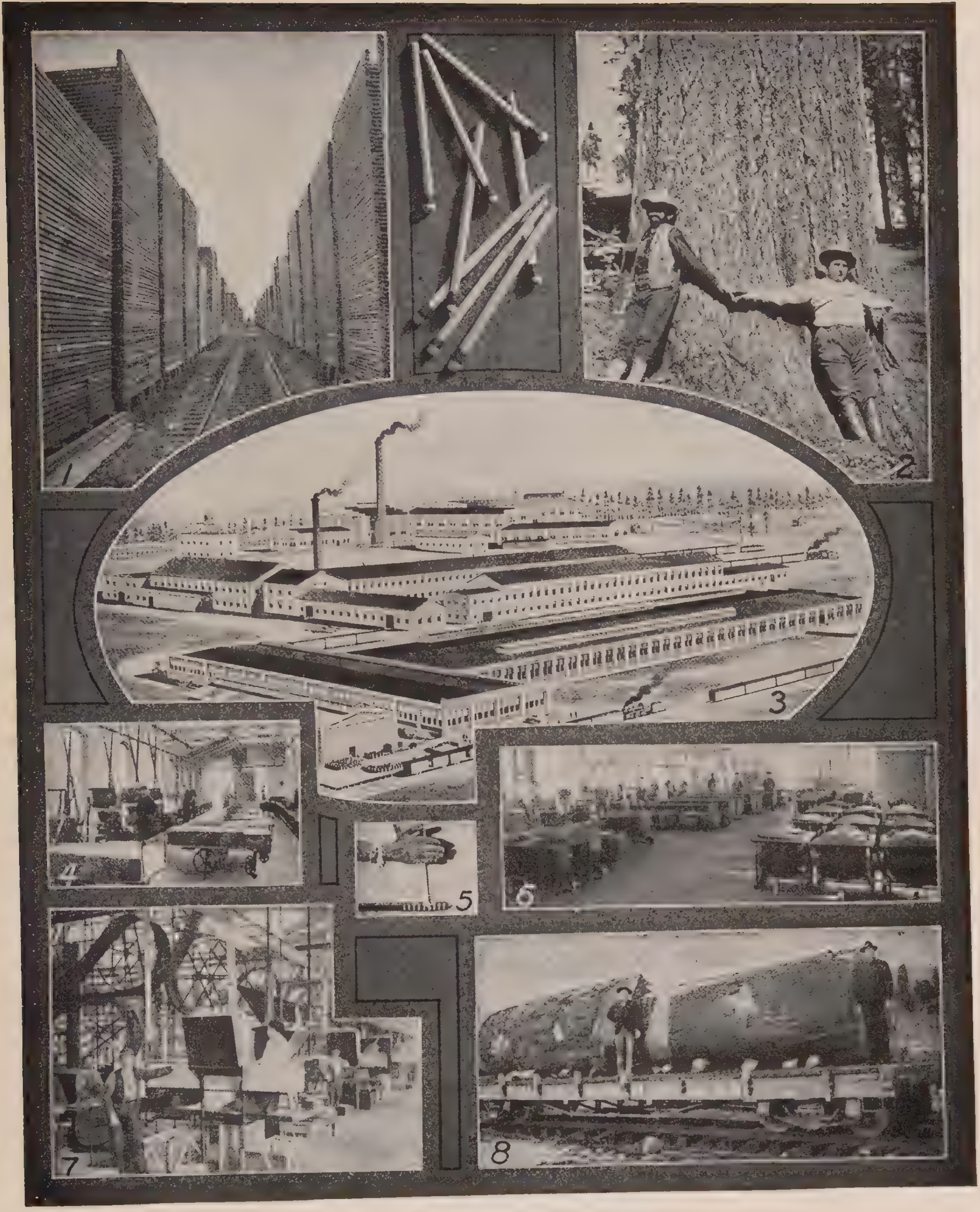
The shiny transparent material known as "cellophane," so much used for wrapping candy bars, cakes, cigars, and other articles, is also made from wood pulp. It has many of the qualities of paper, but strangely enough is made in entirely different fashion. Cellophane is a product of the process of manufacturing artificial silk, and is mentioned again in the section describing rayon, on page 263 of this volume.

MATCHES

WHAT did man do before he had matches — for there was a time long ago when these tiny, indispensable articles were unknown, and when people were forced to resort to very primitive methods to make a fire. They first got flame by rubbing two dry sticks together until the sticks became hot enough to set fire to dried grass.

They then experimented further, cutting a hole in a piece of wood and turning a stick round in it so fast that it became hot and sent out flame. With this flame they were able to kindle some dry material if they worked quickly. Following this discovery came the striking of a metallic stone against a piece of flint, thereby making a spark which could be nursed into fire by touching it to some dried matter. How precious that spark must have been when one had to work so hard to get it!

This crude fire-making outfit was much improved later when iron and steel came into use, for then a metal box called a tinder-box was made to contain the flint; a piece of steel for striking the spark; and a bit of burnt cloth called tinder, that was used for catching the fire.



HOW MATCHES ARE MADE BY THE MILLION

1. Lumber used for matches. 2. Large pine tree in match forest. 3. A match factory. 4. View in composition grinding room. 5. The old way of making fire. 6. View in composition mixing room. 7. General view of match machines which cut the matches, dip them in composition, and pack them in boxes. 8. Some of the giant logs on the way from forest to match factory.

Still man felt there must be a more convenient and better way for creating flame. In 1805 a Frenchman made the first match that in any way resembled those we now use. It was a sort of match with a head made from many chemicals, and to light it the head must be dipped in a bottle of acid which immediately caused the chemicals to flare into flame. Of course it was very inconvenient always to be obliged to have the bottle of acid near at hand. It was a great stride forward, without doubt, but it did not satisfy everybody. Accordingly somebody tried another way; long tapers of paper with one end tipped with chemicals were made. Rolled away inside the end of the paper was a small bulb of thin glass filled with acid. To ignite the taper one must crush this wee bulb with pincers. This was better. It did away with the bottle of acid, but in its place it left the pincers which must continually be carried about, and which were almost as much of a nuisance.

It was an Englishman by the name of Walker who invented the first match like ours, and even then it was not wholly like ours, for it lighted only when scraped between two layers of sandpaper. Yet it was far more convenient and less dangerous than to be dallying with a delicate glass bulb of strong acid that injured the hands if broken by accident.

All this experimenting covered many years. How strange it seems that it should take so long to perfect such a small thing!

Matches are now turned out in vast quantities, and instead of being costly — as they were in the early days — they are very cheap. As recently as the year 1900, practically all the work was done by hand, but now marvelous machines make both matches and match boxes, and are almost superhuman in their action.

The matches of an earlier day were tipped with yellow or white phosphorus. Yellow phosphorus is very dangerous, being such a powerful poison that a grain of it will kill a man. Those who made matches were not infrequently poisoned by it, contracting a disease that ate away the bones of the jaw. But in accord with the modern practice of insuring the safety of workers, the use of yellow phosphorus was prohibited by an international convention at Berne in 1906.

THE SAFETY MATCH

To-day the safety match has almost crowded out all other varieties. It was invented by two Frenchmen at the time the Belgian government offered a prize for a match to be made with no poisonous phosphorus in it.

Certain matches will strike only on the box. In these, a necessary chemical is left out of the match tip, but is included in the sandpaper-like scratching surface on the side of the box. The chemicals are brought together by the act of striking, and cause the flame. In line with safety practices, matches are now often dipped in a solution which prevents the wood of the match stick from glowing after the flame has been blown out.

In the manufacture of matches, a machine peels a thin spiral layer (or veneer) of wood from a log. Another machine takes thin pieces of wood and fashions them into the familiar sliding boxes, turning out from six to ten thousand of the completed containers each hour. A third machine takes the wood and carries it continuously through the processes of splitting, dipping, and drying, the finished matches emerging from the machine at a rate of over seven hundred thousand an hour. Boxes and matches meet at this stage of manufacture, and the same ingenious machine opens each box, fills it with matches, closes the box, and delivers it for wrapping.

A popular form of safety match is now made of thin cardboard. A number of these matches are fastened into a little paper "book" or container, from which they are torn when needed. Advertising messages are usually printed on the outside and sometimes also on the inside of these paper covers. The advertiser pays to have his message thus distributed and this helps to reduce the cost of the matches to the consumer.

In some parts of Europe, also in Mexico and other Latin-American countries, another form of matches called "vestas" are commonly used. These have the regular safety tips but the sticks, instead of being made of wood or cardboard, consist of short lengths of wax-covered string.

In contrast with the early methods of creating flame, the modern match is not only very cheap but remarkably efficient, giving results that are quick, sure and safe.

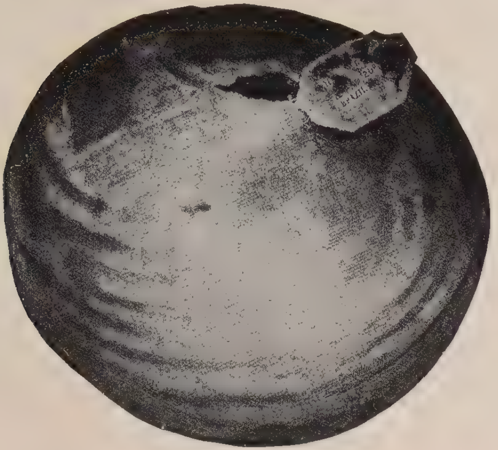
Courtesy Firestone Tire & Rubber Co.

RUBBER PLANTATION IN LIBERIA, AFRICA

From such trees comes the milky fluid, the "latex," which is the basis for our rubber articles.

THE STORY OF RUBBER

THE romance of modern industry lies in the fact that it is so very modern. As we trace out the story of one great industry after another, the marvel is that from the point of view of the time covered the history of each is so short. Products which are taken for granted as comforts, conveniences, and apparent necessities of our present life, prove to date back only a brief thirty, fifty, seventy-five, or at the most one hundred years.

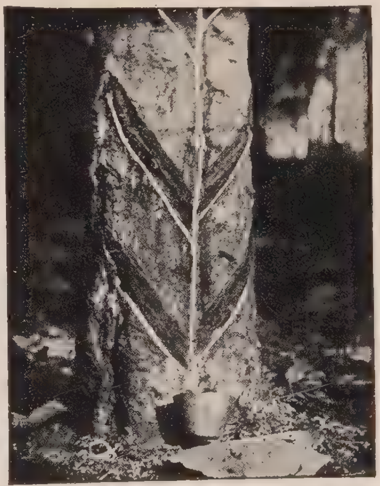


BALL OF RUBBER

Rubber is so familiar in the daily life of the American home that we are hardly conscious of its omnipresence. We protect ourselves in wet weather by rubber footgear, rubber garments, rubber hats; we water our gardens with rubber hose; we fit up our bathrooms and kitchens with convenient rubber articles; we play our games with baseballs, golf balls, tennis balls, made with rubber as a basis; we depend on rubber connections and rubber insulation of wires for the service rendered by our telephone, our electric light system, and our street-car system, while our firemen would be well-nigh helpless to protect our homes without rubber; and we are saved many a jolt and jar as we ride abroad by the rubber tires with which modern vehicles are shod. Each one of these great modern industries which we are studying is fascinating in giving us a picture, taken from its own particular angle, of the rapid progress of our world within the possible lifetime of a single man.

AS RUBBER WAS DISCOVERED

When Columbus landed in the West Indies and set his men to make clearings in the forest, he noticed that there oozed out of certain trees a milky fluid. Spaniards visiting the New World in the sixteenth century found the natives playing games with a ball made of a peculiar dark substance that formed from the milk of a tree. Two hundred and fifty years passed before much more attention was paid to this sticky substance which the French called "caoutchouc," or "weeping tree," from two Indian words, — *caa*, meaning "tree," and *o-chu*, the verb "to weep." By this name, borrowed into our own language, it might have gone for all the years to come if an enterprising Englishman had not discovered in 1770 that pieces of this substance would erase pencil marks from paper, and put it on sale for this purpose; whence the artists, with true Anglo-Saxon practicality, called the stuff "rubber" because it rubbed, adding sometimes to the name by terming it "India rubber," since it came from the West Indies. So it is from the present schoolboy and desk use that rubber originally got its English name, although this part of its work is now one of its smallest services to mankind.



Courtesy Hood Rubber Co.

METHOD OF TAPPING

Fortunately for the march of our civilization there are always in our midst inventive souls

A TAMBO, OR SHELTER, ON THE BANKS OF A RIVER IN THE AMAZON RUBBER DISTRICT

It is surrounded by an endless tropical forest and jungle. For thousands of square miles stretches a wilderness of beautiful trees and flowers, of strange birds and animals.

whose curiosity and love of research lead them to experiment patiently and persistently with any new substance that comes their way. Stories were brought home by sea captains and travelers that the natives of countries where the caoutchouc tree grew made ordinary garments partially waterproof by pouring over them this sticky tree-milk. Chemists began to experiment with this new substance. Two names should always be remembered in the early story of the industry,—Thomas Hancock, a business man in England, who devoted much time and money to the making and marketing of a variety of rubber articles, such as shoes, hose, carriage tires, and suspender cords; and Charles Mackintosh, who in 1823 in the city of Glasgow invented a process of spreading rubber between two pieces of cloth and holding them together under pressure until a waterproof cloth was produced. To this day we acknowledge our indebtedness to this inventor by calling waterproof coats "mackintoshes." The first coats were crude affairs, but they were useful as a protection against Scotch mists and English fogs. Similar garments were soon made in America, but here they did not work so well. The English climate had been fairly uniform. In the heat of our summers the coats became sticky and their rubber oozed away; in the cold of our winters they stiffened and became as hard as board. Dissatisfied purchasers threw them back on the luckless manufacturers with complaints of utter dissatisfaction, and the industry was on the point of coming to an inglorious end in the bankruptcy courts.

Then another inventor, Charles Goodyear, an American, steps into the scene, and for the next twenty-five years holds the center of the stage with his process for hardening and stabilizing the raw product. Rubber by itself was not commercially serviceable. It must be combined with something else or treated by some process to make it useful. Goodyear worked in his kitchen with saucepan and rolling pin, mixing this sticky dough with one substance and another, trying it at one heat and then another, until finally, when his money was exhausted and he was shabby and half starved in the struggle to maintain himself and still carry on his experiments, he hit on a combination of rubber and sulphur, brought together under certain conditions of heat, which accomplished the desired result. The problem was solved; rubber became a useful and workable commodity. The process thus discovered by an American was named by an Englishman "vulcanization," from the old Roman fire god "Vulcan," whose heat was necessary to secure the result. Today, as in the first days of the invention, every bit of rubber which we use is vulcanized.

THE RAW PRODUCT AT ITS SOURCE

In each industry we start with a raw product and wind up with one or many finished products. The industries which we have been describing thus far in this volume are comparatively simple in their dependence on a single raw product. Wheat is a plant product which must be garnered and put through certain refining processes before it is suitable for use as a food; the lumber, paper, and rope industries are concerned with the purifying and adapting of a vegetable product to desired uses; iron ore and fuel are brought together under certain conditions, and iron or steel result. The rubber industry is more complicated in needing several raw products; but at the basis there must always be the original milk of the rubber tree, or, in the case of synthetic or artificial rubber, its chemical substitute.

Raw rubber, caoutchouc as it is technically called, is a vegetable product of the tropics. To see the milk oozing from the rubber tree at the slash of a knife into its bark one must leave our temperate zone and travel either into the jungle regions where it grows wild, or into the tropical or semitropical countries where rubber plantations have been planted and tended, and its cultivation is an industry in itself. Many species of tropical trees are milk-producing, though only a very few have been found to be commercially profitable; while many plants not found in the tropics have the same qualities in their sap as do the rubber trees. Milkweed is one of these, and some attempts have been made to extract rubber from its thick white juice. These experiments, however, have not been successful. The white juice of the rubber tree is called "latex," and just as all the sap from the maple tree is not sugar so all the latex is not rubber. The globules of rubber rise on the sap as cream does on milk and must be separated from it. This separating may be done in several different ways. In mills it is done by artificial heat, or a combination of natural heat and chemicals; but in the hot countries natives do it by processes they have themselves invented.

When latex is to be collected, men start out into the forests or jungles carrying knives and a great many little clay or metal cups. They first make an oblique cut across the trunks of the rubber trees and then, having opened the veins where the latex flows, they fasten at the lower end of the gash one of the small cups by sticking it to the tree with a bit of clay. These cups are emptied into a pail each morning.

The latex, however, has so much water in it that if it were to remain in the pails it would soon ferment. So the natives dry and cure it. They first dip into the sap a piece of wood in the shape of a paddle. This paddle they hold in the smudge rising from a fire made of nuts which grow on a particular variety of palm tree. The paddle is waved about in the smoke until the rubber on it is thoroughly cured; then it is dipped again in the latex and thrust into the smoke once more. This process continues until a large ball of rubber about the size of a man's head is cured. This is then stripped off and is ready to be sold. The balls are called "biscuit rubber"; in some places the "biscuits" are smaller and of a different shape, and these are called "thimbles," "knuckles," or "nuts."

RUBBER IN COMBINATION

Interesting as it would be to follow rubber from its native jungle or plantation to our own shores, we are less concerned with this raw substance than with the results as they issue from our factories. All industries have certain similarities. The raw product as it comes from forest or plantation, from field or mine, must be cleansed of impurities. Plantation rubber is usually sufficiently clean so that its sheets need only be brushed; but "wild" rubber must be thoroughly washed and then most carefully dried under conditions which will not allow it to deteriorate. From this time on the business of mixing the rubber is a chemical process requiring extreme care and accuracy.

Pure rubber is soft and elastic. It becomes sticky when heated, and melts at a temperature of about 300° Fahrenheit. It does not dissolve in water. Indeed, in one sense, it does not dissolve in any of the substances with which it is combined; it takes these liquids, these solvents, into itself, and swells with them as a sponge swells with water. To get dry sulphur powder and chemicals like carbon black, zinc oxide and other ingredients of the chemist's formula into the original raw rubber is a matter of careful and skilful mixing under most exact conditions of temperature. Enough for us that the chemist does it, and that the various kinds of rubber come out suited for our uses. It has been estimated that rubber is a vital part of more than 32,000 different commercial products.

Rubber stretches to a greater degree than any other substance. Herein lies the secret of its great usefulness. As it stretches it stores energy. Stretch wood or steel a very small proportion of their length in any given piece, and they give way or break. But rubber can not only be stretched an amazing amount; it will also hold in itself the desire to return to its natural or original shape or length. That desire to return may be measured as the energy stored in the rubber. In returning to its original length the rubber will release that energy and drive a stone out of a sling shot or do any other piece of work set it.

THE NEXT STEP

Even a rubber mixture is not the finished product. If we knew nothing of the previous steps we might almost call the carefully prepared rubber mixture the raw product, for such it is to the multitude of industries in which it is used. As the native of the West Indian jungle spread the sticky tree-milk on his clothes, so the modern manufacturer makes his molds or designs for rubber garments, rubber shoes, rubber hose, or rubber tires out of some fabric like cotton and coats them or lines them or in some way treats them with rubber. Or, if the product is to be of solid rubber, he must have molds in which to shape it. The recent progress of the rubber industry has depended in large measure on the vast number of machines designed to carry on the later processes of the transformation of rubber into every conceivable article, from gas masks and rubber gloves to the huge conveyor belts of the modern mill.

SYNTHETIC RUBBER

Scientists have succeeded in making artificial or synthetic rubber that is equal and in some ways superior in quality to the natural product. The basic materials which go into the making of one form of synthetic rubber, known as neoprene, are simply coal, limestone, water and salt. All of these materials exist in vast quantities right here in our own country. Although the cost of making neoprene exceeds the cost of natural rubber, it is most comforting to know that if for any reason our regular supplies of crude rubber were cut off, we could produce in this country from our own raw materials, a synthetic rubber that would serve practically all the uses of natural rubber. In spite of its higher cost, neoprene is manufactured in considerable quantities because, for certain uses, it is better than the natural product. For instance, it lasts much longer than natural rubber in uses where it is exposed to oil, sunlight or heat.

GUTTA-PERCHA, BALATA AND CHICLE

Rubber has its companions, though not its rivals, in other substances from the milk of other tropical trees. One of these is gutta-percha, which resembles rubber in being waterproof, and also in resisting the passage of electricity. As a good insulator it is used in factory work and in submarine cables. Balata, a somewhat similar substance, is used in belting and in covering golf balls. Chicle, more plastic than caoutchouc and more elastic than gutta-percha, is the base of chewing gum.

THE PNEUMATIC TIRE

More than three-fourths of all the rubber now used in the United States goes into the making of tires. Millions of acres of rubber trees in tropical countries are needed to meet this demand.

The romantic story is told that the pneumatic tire was invented by John Boyd Dunlop in 1888 to enable his small son to beat a larger boy in a tricycle race. To Dunlop must go the credit for introducing this invention at a time when bicycles were gaining popularity, and for giving it the impulse that led to its universal use.

Dunlop, a Scotch veterinary surgeon residing in Ireland, patented his pneumatic tire in England in 1888 and 1889. Since he first applied it to the wheels of his son's tricycle, there has been no break in the history of its manufacture. Dunlop's first tire was a tube of rubber, protected by a canvas cover which was tacked to the wooden rim of the wheel.

His attempts to introduce his tires to cycle manufacturers were discouraging. Yet when it was proved that pneumatic tires were speedier than the usual ones of solid rubber and would more readily withstand and absorb shocks and vibration, interest in them grew and he was given the financial support needed to form a company for their manufacture.

From this small beginning has sprung a giant world wide industry which now makes many millions of pneumatic tires annually to smooth the passage of travelers on the highways of the world.

HOW PNEUMATIC TIRES ARE MADE

There are few of us who have not mended an automobile tire, or at least watched as one was being repaired in a tire shop. It is then hardly necessary to attempt to describe how such a tire looks in its finished form. It is enough to note that the modern pneumatic tire ordinarily consists of a rubber inner tube to hold the air and a protective outer casing of rubber and fabric, much like John Boyd Dunlop's tire of 1888.

In the tire industry, as in other manufactures, the hand work of earlier times has been largely replaced by marvelous machines which perform their duties with a speed and exactness impossible to equal with human labor. To the machine age we owe the long wear and safety from accident which mark the tires of the present.

The automobile tire is built up of several layers or "plies" of rubber-coated cord fabric over which are placed thick treads and thinner sidewalls of rubber. The rubber used for the tread contains a considerable amount of carbon black. This makes it very tough and able to give many thousands of miles of service on the road before wearing out.

Strips of the rubber-coated cord fabric are first built up on a tire-shaped form. Layer after layer is added until the desired number of plies is in place, and finally the rubber tread and sidewalls are put in place. When the "raw" tire is removed from this form, it is mounted upon an inflatable bag and enclosed in a heavy steel shell or mold.

Now the tire must be "cured" by vulcanizing to weld all of its units into one sturdy whole. This is accomplished by inflating the bag with air, steam, or hot water (according to the process used) and subjecting the whole to high-pressure steam. The time used in vulcanizing is from one and one-half to three and one-half hours. This process demands the most careful watching by highly skilled workers to make sure that the tire receives exactly the right amount of cure. If the curing is allowed to continue too long, the rubber is made brittle; if too short a cure is given, the rubber remains soft.

The finishers take the tire at this stage and remove the marks left by the mold. They cleanse the outside by scrubbing, and paint the inside with a mixture of talc to prevent it from sticking to the inner tube.

Thus another tire is added to the thousands that daily pour forth from the factories.

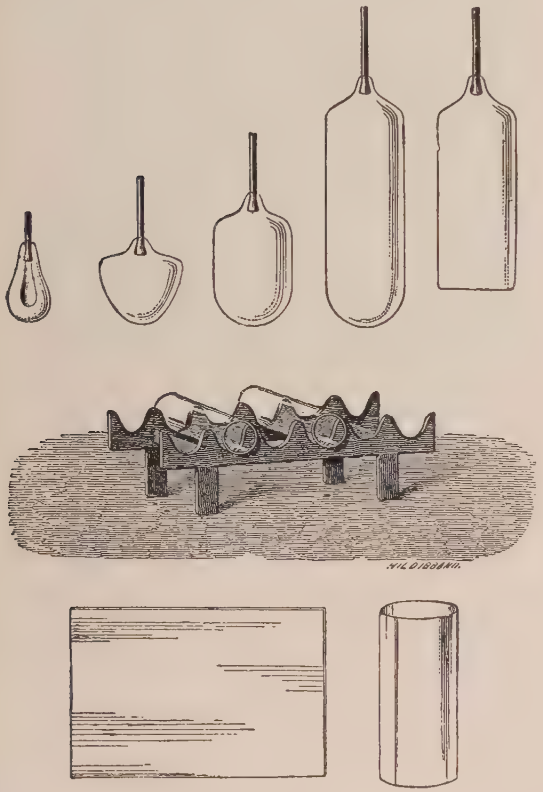
Dunlop Tire and Rubber Co.

GLASS-BLOWERS MAKING BOTTLES BY "LUNG POWER" BEFORE THE INTRODUCTION OF AUTOMATIC MACHINERY. COMPARE THIS SLOW AND ARDUOUS METHOD WITH THE MODERN PROCESS ILLUSTRATED ON PAGES 222 AND 223.

GLASS-MAKING

THE date and origin of the first glass-making are unknown. On the tombs of Beni-Hassan at Thebes, dating back 2000 years B. C., there are pictures of Theban glass-makers at work; a glass bead bearing the name of Queen Hatasou, who lived about 1500 B. C., and was the wife of Thothmes III, was also discovered at Thebes. When Cæsar Augustus subdued Egypt in 26 B. C. he ordered that glass should form part of the tribute of the conquered people. Accordingly quantities of glass products were sent to Rome, where the fastidious Romans eagerly bought them up and eventually made glassware one of the large export trades of the Egyptians. During the reign of Tiberius (14 A. D.) the industry was taken up in Rome itself, and soon the Romans outrivaled their predecessors in the shape, coloring, and cutting of glass objects. In fact, the many glass household articles found in Roman tombs prove that glass was in very common use in those days. In ancient provinces of France glass relics have also been discovered, showing that at an early date the Gauls were rivals of the Romans in glass-making. Primitive glass work was found in Spain as well.

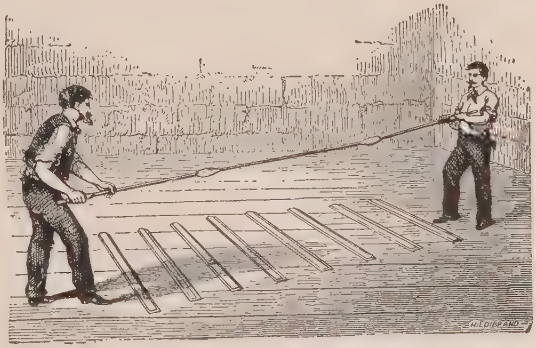
Then the barbarian hordes swept down upon Rome and the adjacent countries, and all these industries perished and were not again revived until Constantine the Great moved the Byzantine capital to Constantinople and drew there artists of every variety. Then gradually the Venetians, by nature great travelers and traders, came to the front as glass-making artists. Probably at St. Sophia they saw the windows of colored glass, a product quite new to them, and became interested in copying it. They had long made pictures in mosaic, using bits of vari-colored glass. Now on their tiny island of Murano they began experiments which resulted in the beautiful old windows of St. Mark's, as well as in numerous marvels of spun and blown material. Venetian glass, still made at the old Murano works, is world-famous. The art was for centuries kept secret, and no glass-maker of the Republic was allowed to take up residence out of Venice on pain of death. These craftsmen were regarded with great respect, and were allowed to marry with the nobility. The most wonderful work of the Venetians was their imitation pearls of blown glass, their colored glass, and their delicate



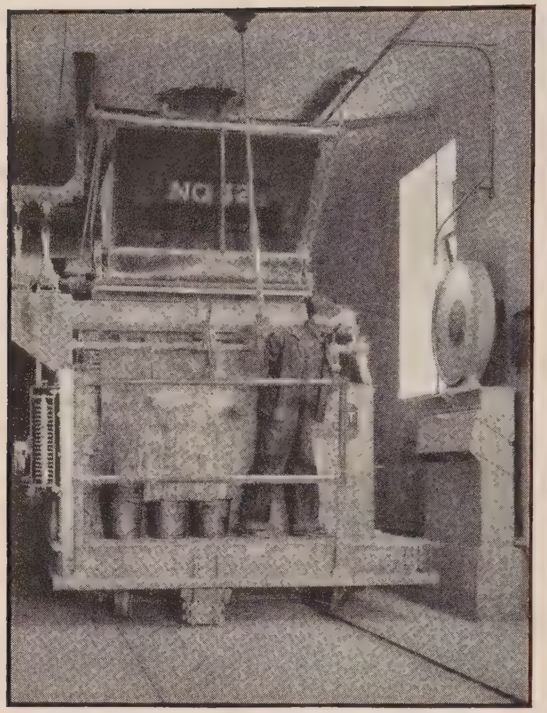
BLOWING OF SHEET GLASS, FIRST INTO A PEAR-SHAPED MASS, THEN A CYLINDER, WHICH IS OPENED INTO A SHEET

GLASS FURNACE

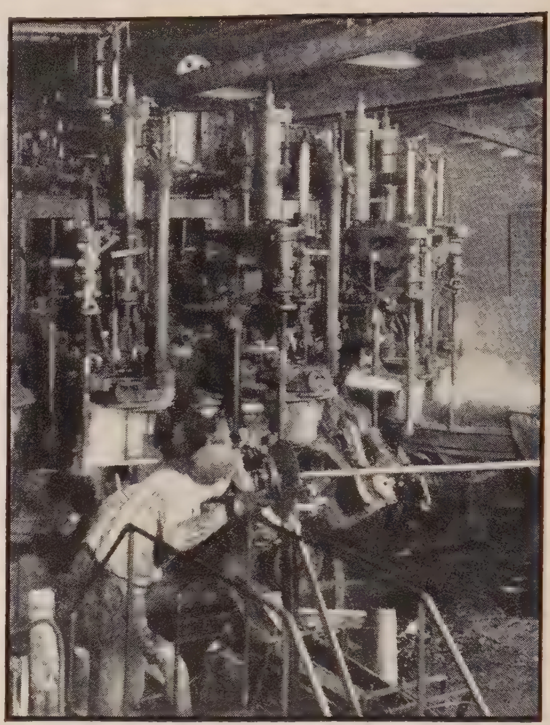
THEBAN GLASS BLOWERS



DRAWING OUT GLASS TUBE



COLLECTING AND WEIGHING INGREDIENTS



Photographs, Owens-Illinois Glass Co.

MACHINE WHICH BLOWS FIFTEEN BOTTLES AT ONE TIME

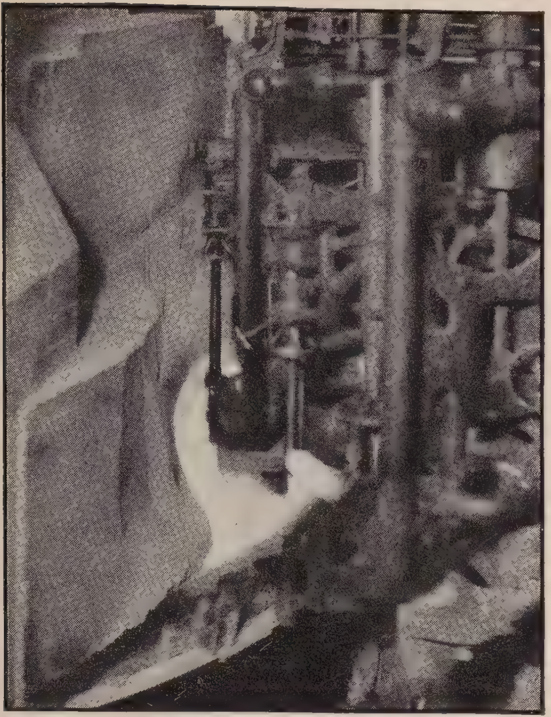
filigree or spun glass. So popular did spun glass become that we read of a foreign prince who made a great sensation by appearing in Paris with curls of finest black spun glass.

DEVELOPMENT IN GERMANY, BOHEMIA, AND FRANCE

Germany, meanwhile, began to produce glass of a very different type—great vases, tankards, and drinking goblets decorated with coats-of-arms in enamel. The most ancient of these vases, having upon it the crest of the Elector Palatine, bears the date 1553, and may be seen at the Kunstkammer, Berlin. In Nuremberg, Albrecht Dürer and other renowned German artists were gaining success at stained glass-making; to Kunkel, a Saxon chemist, Germany is indebted for the ruby-red variety.

Bohemia, in the seventeenth century, surprised the world with an engraved glass done either by lathe or diamond and worked in gold or colors. Belgium and England were all this time turning their attention to fashioning crystals and cut glass. Very beautiful glass was also made in France from the sixteenth to the seventeenth centuries, and in the various museums drinking glasses and vases manufactured for the French kings may be seen. About this time a colony of Venetians settled near Limoges; and the people, already clever at enamel-work, began experimenting with stained glass. After many difficulties they mastered the art, and their work is still found in many of the old French cathedrals. At first this glass was faint in color and followed the conventional designs of the orientals, whose Mohammedan religion forbade them to make human likenesses; later, the tones of this early glass deepened, and the Bible pictures, or scenes from the lives of the saints, took the place of the floral traceries. These tales in glass served two purposes: they beautified the churches, and they acted as story books to the masses, who were unable to read.

At present glass-making has widened its scope. Not only do we purchase numberless glass objects for decorative purposes, but we use for



SUCKING IN A "CHARGE" OF MOLTEN GLASS

Photographs, Owens-Illinois Glass Co.

FINISHED BOTTLES READY FOR PACKING

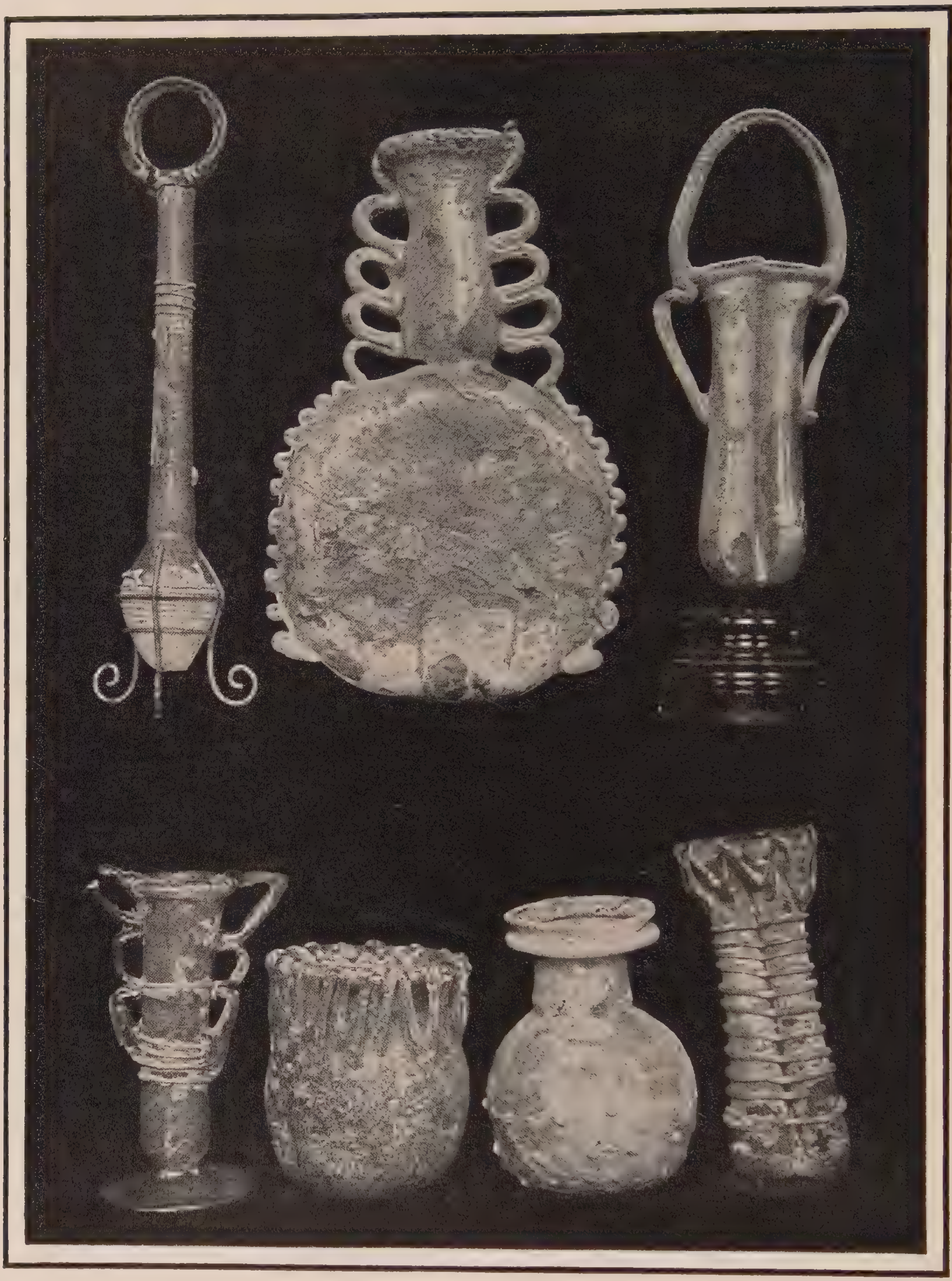
household conveniences more glass than any other nation in the world. American artists like La Farge and Tiffany have designed and executed exquisite stained glass, and they have turned out art glass of striking beauty. In addition to its esthetic value glass, as a non-conductor of electricity, has taken an important place in industrial and scientific fields. Thermometers, test-tubes, lenses, spectroscopes, microscopes, and electric-light bulbs are all dependent on glass for their being. The looking-glass, in early days a pool of still water, and later a sheet of polished metal, is now made from thick plate glass; and no longer must man resort to oiled skins or paper to keep out the cold or let the light into his dwelling. Wire-glass, used for skylights, etc., was invented by Frank Schuman, an American, and has proved to be most useful where large, heavy panes of glass are employed; not only does the wire incorporated in the glass help to support the weight of the material, but it also catches the pieces and prevents injury should the glass break and start to fall.

HOW GLASS IS MADE

Glass is made from a mixture of silica, a form of sand or quartz, with some other material. To make window-glass, soda and lime are blended with the silica; for bottles, a small amount of oxide of iron may also be present; for crystal, potash and oxide of lead. For enamels, oxide of tin is mixed with the soda, lime, and silica. Silica may be found almost everywhere. Rock crystal, sandstone, flint—all contain silica. The art in the glass-maker's trade lies in knowing just what proportion of these ingredients to put in. When these materials have been properly measured out they are melted together until they are reduced to the consistency of thick molasses.

FLAT GLASS

Sheet or window glass was formerly made by first blowing the glass into a cylinder or a large circular tube which, after it had attained the proper size, was split, re-heated and



GRÆCO-ROMAN GLASS VASES

Reproduced from specimens at the Museum of Fine Arts, Boston.

flattened. Originally, these glass cylinders were actually blown by glass blowers. Later machines were developed to blow the glass automatically. At the present time flat glass is all made by drawing the glass in sheets directly from the molten mass in the tank and gradually cooling it.

The difference between window glass and plate glass is that plate glass, after it has been drawn from the tank, is ground and polished on both surfaces by large grinding wheels; in other words, window glass retains the so-called fire finish as it is drawn from the tank, whereas plate glass has a ground and polished surface.

NEW KINDS OF GLASS

Out of the laboratory have come and are coming new kinds of glass for entirely new purposes. For all past ages glass has been brittle and easily breakable; now we have "laminated" or "shatterproof" glass used by all automobile manufacturers and which, as the name implies, does not shatter when broken. This glass is manufactured by laminating two pieces of glass with a thin transparent sheet of cellulose acetate between and running them through a compressing machine which presses them firmly together into one piece.

Then there is a "non-breakable" glass which will actually bend without breaking. Glass cooking utensils are now made that can be used directly over hot flames.

Most glass manufactured is transparent but some glass is translucent. Now hollow building blocks of glass are being manufactured which are translucent and which also have insulating properties. These blocks let in various degrees of light, although objects cannot be seen through them.

Spun glass, or glass fiber, is fine for insulating walls, because it is fireproof and because the millions of air pockets between the fibers keep out heat or cold. Spun glass can be woven into textiles and is being used for theater curtains since it cannot catch fire.

STAINED GLASS MEMORIAL WINDOWS IN THE SECOND CHURCH, BOSTON

HOW THE COOLING IS GRADED

The annealing, or cooling, has much to do with the quality of glass. If cooled quickly in the air, it becomes delicate and brittle; if cooled gradually, it is much stronger. Hence ovens of slowly diminishing temperature have been invented where the glass may travel from one oven to another and become cool by almost imperceptible changes. Sometimes this process of graded cooling takes many hours. Until

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CHINA DECORATORS AT WORK, NEAR KYOTO, JAPAN

the invention of these cooling tunnels, weeks were often consumed in annealing glass.

CUT GLASS

Cut glass is made upon grindstones moistened by wet sand, or is cut by revolving emery wheels. After cutting it is polished with putty powder, jeweler's rouge, and chamois-skin. Pressed glass, made so extensively in America, is much like cut glass but lacks the sharp edges and prismatic coloring. It is, however, much cheaper and therefore has a wide sale. Stained glass may be colored throughout or simply tinted upon the surface. The coloring matter is blended with the mixture of sand, lime, and soda, but allowance must be made for the changing of tone in the firing.

HOW CHINA IS MADE

WHEN did man first begin to make dishes? To trace the origin of pottery and china we must travel back over centuries of history, and even then the date will elude us. Most races of the world soon discovered that they needed some sort of dish or bowl. Perhaps it was seeing a footprint harden in the sun-baked soil that first set them thinking they might fashion dishes of clay and dry them in the sun. But until man acquired the art of glazing his pottery so that moisture could not penetrate it, and of baking it in the fire, it was not really of much practical value.

The baking or firing of pottery was probably a chance discovery. Some bit of primitive clay-work may have fallen into the blaze, and instead of being burned came out hard and strong. One fact is certain, that until man learned to make fire and use it he could have made none of that ancient glazed earthenware, the relics of which can now be seen in many of our museums.

The Chinese and Japanese were skilled in glazing pottery fully three hundred years before the secret was known to European races. The Egyptians put a crude glaze on some of their earthenware, and so did the Greeks and Romans, but none of them equaled the perfected workmanship of the Asiatics. The Saracens and Arabs also discovered a method for enameling pottery with melted tin, and when the Crusaders returned from their pilgrimage to the Holy Land they brought back this art to certain parts of Europe. The people of Limoges, France, for a long time did beautiful enamel work; then came the turmoil of war, and the art was lost and never re-discovered. While this experimenting was going on, the Italians were making and decorating a sort of earthenware called Majolica, which, when baked, came out with a

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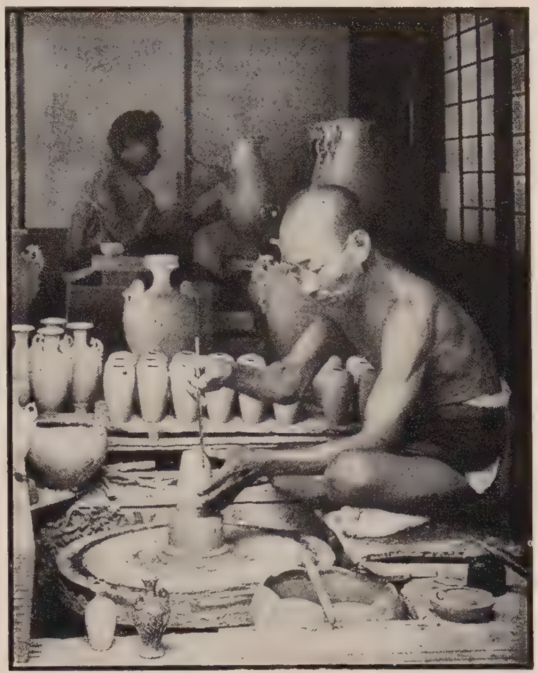
PREPARING CLAY AT PORCELAIN WORKS



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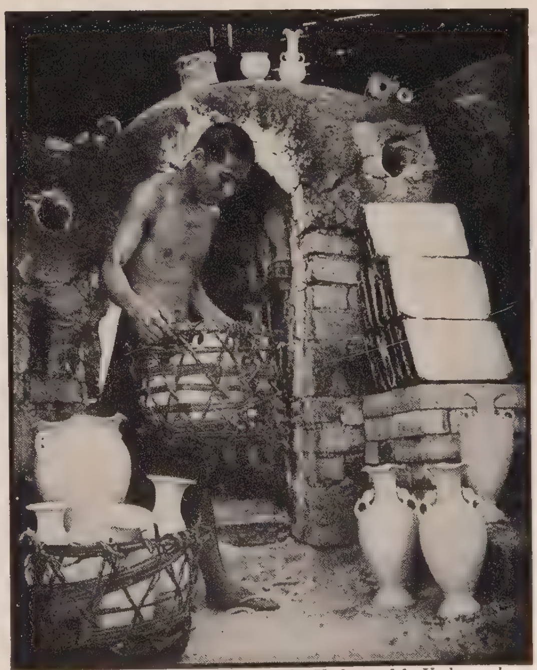
JAPANESE POTTER AND HIS WHEEL



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REMOVING POTTERY FROM THE KILN

glaze formed by the blending of its colors with lead. Later they too learned the Saracen art of glazing with tin.

If all these nations had shared the results of their experiments, we might have had china on our tables centuries before we did. But every country feared every other. Hence guilds, or unions, were formed to guard the secrets of every trade. As a result, every nation was eager to steal the processes of every other. It was a period of scheming and sacking, of treachery and violence. No methods were intrusted to writing lest they be stolen. The men working at various trades carried the secrets of their craft in their minds. It therefore came to be part of the policy of warring nations to capture and torture artisans in the hope of wringing the story of their trades from them. If this failed, the men could at least be killed, so that the art would die with them. What wonder that it took so long for discoveries to spread through Christendom! Each country had to work out for itself problems which some other might have answered for it. Palissy, the French Huguenot, starved himself and burned all his furniture as fuel during his sixteen years' struggle to discover how to obtain the enamel glaze he had seen on a Saracen cup. His story is a fascinating one.

Haeger Potteries

MIXING GLAZES

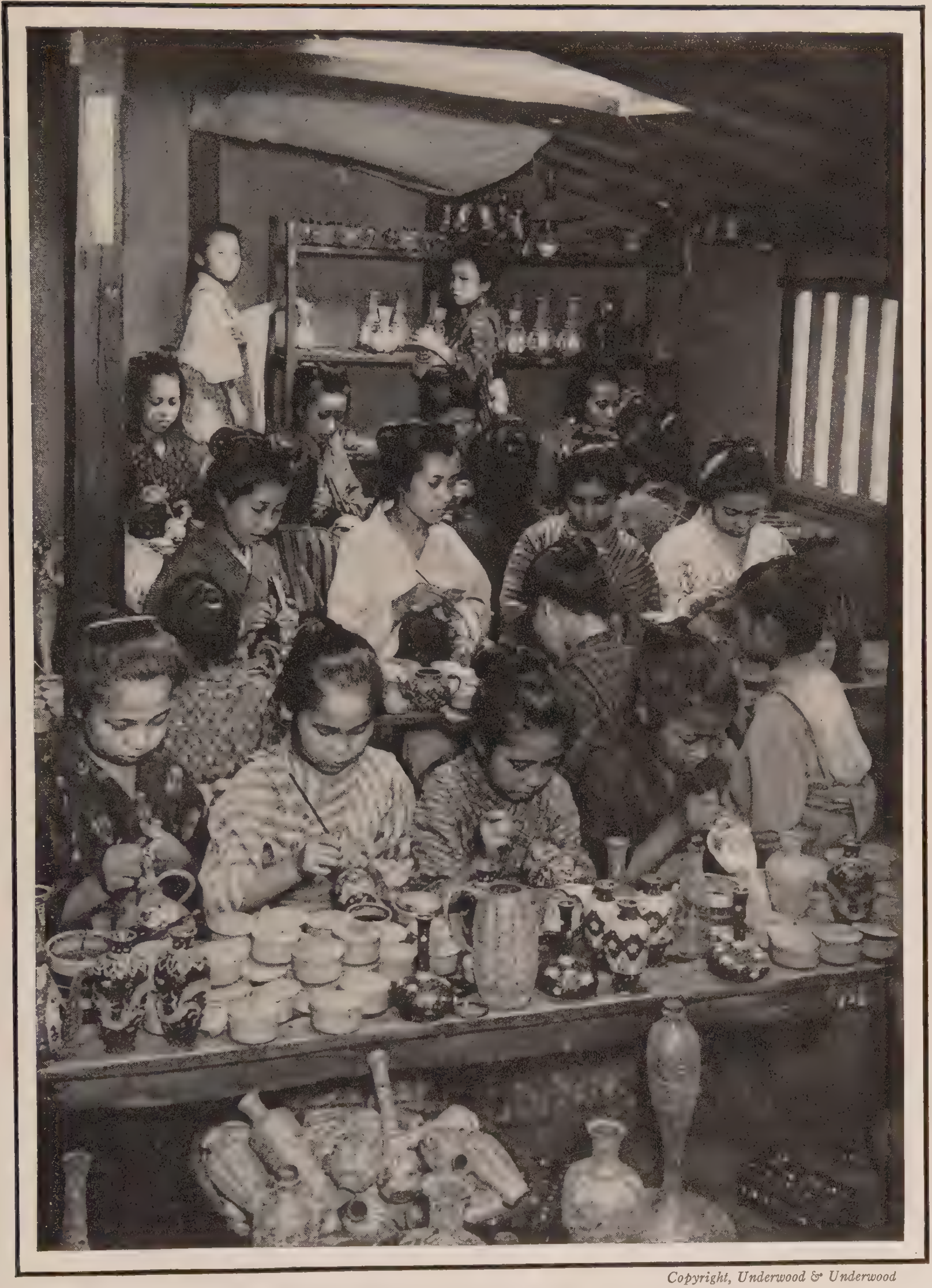
In Germany, also, the people were wrestling with the puzzle of glazing pottery. They were making a clumsy sort of grayish earthenware with figures of blue, brown, and white for decoration; after sprinkling this ware with common salt and baking it, it came out with a rough glaze caused by the blending of the salt vapor with the clay.

Haeger Potteries

APPLYING THE GLAZE

HOW EUROPEANS GOT ON WITHOUT DISHES

All this time people had no such thing as china dishes. The poorer classes ate from tables with thick wooden tops, in the center of which was hollowed a trough for the food; those more well-to-do had wooden bowls and cups, and used



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DECORATING CHEAP POTTERY FOR FOREIGN MARKETS, KYOTO, JAPAN flagons of horn or leather; the rich had their bowls fashioned from pewter or brass. Life was very simple in those days. There was little variety in the food, and therefore few dishes were required. Tea, coffee, and cocoa were unknown, so there was no call for cups and saucers; nor were there soups, vegetables, or desserts. Each person ate with his fingers from the big trencher in the middle of the table, or from his own bowl. Since a guest more often than not ate out of the same dish with his host, and since all armor was laid aside during the meal, you can readily see that it was a mark of great trust and friendship to be asked to eat with anyone. Then the thirst for travel and trade developed. Nations began to send ships to other parts of the world. English and Dutch merchant vessels sailed to China and Japan and brought back a myriad of products hitherto unknown—such as tea, coffee, strange fruits and vegetables, silks, and porcelain.

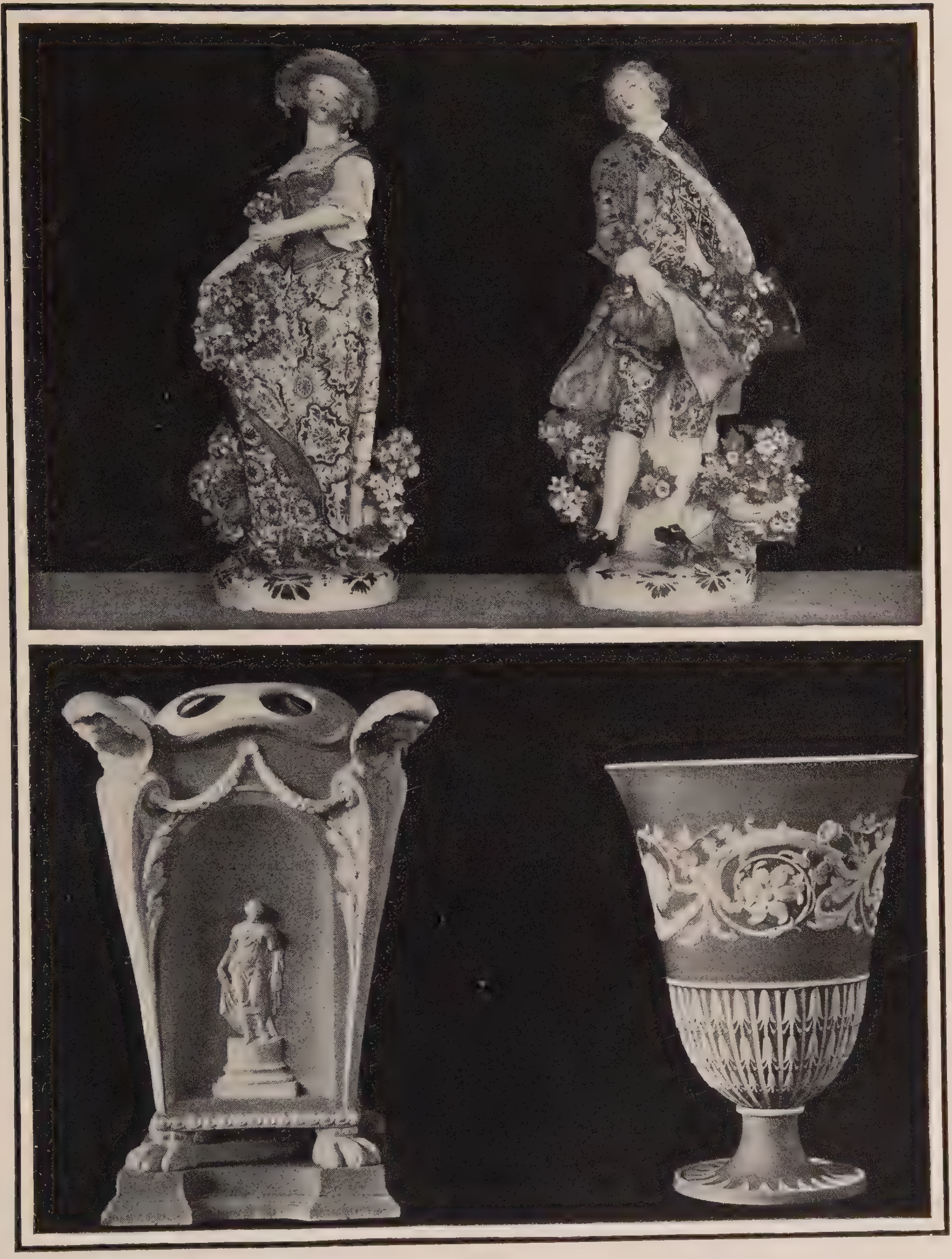
What a sensation all these new things made in the western world! With this increased variety of foods and drinks more dishes were needed, and people eagerly bought up the dainty blue and white china sent from the Orient. The thin teacups made without saucers by the Chinese and Japanese, however, were found to be impracticable in England, where oak or mahogany, instead of teakwood tables, were used; the heat struck through the delicate ware, marring the English woods so badly that saucers were necessary. Then, too, fruits and vegetables could not be mixed in bowls with meat. There must be plates. So Dutch workmen, taking pattern from the Chinese ware, set about making a blue and white china which they called Delft, and which had a hard, shining glaze upon its surface. How they made it they would not tell. As all this china was fashioned from oriental designs, it was without handles; it was many years later before teacups with handles were invented. Not to be outdone, England took up china-making too, but got no results beyond crude, salt-glazed wares such as Germany was making. How did the Chinese make that pure white porcelain of egg-shell delicacy? Everybody wondered. And what was the key to that marvelous smooth glaze?

HOW KAOLIN WAS DISCOVERED

From the seventh to the tenth century the Chinese had not only perfected the art of china-making but had guarded well their method. They now looked on with sealed lips and viewed the struggles of their neighbors. Foreigners were not permitted to come into China, hence there was no way to find out the secret. At last there was someone (as there always is) who needs must tell the story. A Chinese teacher traveling in Europe glibly explained that the beautiful white porcelain of the Chinese was made from nothing more mysterious than a fine white clay called "kaolin." It looked, he said, like ground wheat. This was the hint for which European chemists had been waiting. They began to hunt in the soil for a white clay, like flour.

In 1701, the King of Poland, who had become interested in the search for kaolin, set a chemist by the name of Böttger to looking for it. Böttger had already had some success with making earthenware, so the art was not entirely unknown to him. He was, moreover, something of a scholar — a fussy little man, with florid face and powdered wig; surely a strange sort of person to be sent hunting kaolin! What is more remarkable, he proved to be exactly the right person to go on the quest, as you will see.

One day, when his servant brought home his freshly powdered wig, Böttger complained that it felt unusually heavy, and so much fault did he find that at last the terrified servant confessed that he had sprinkled it with a new kind of powder. The powder was brought and Böttger examined it. He found that when mixed with water it made a clay not unlike that from which the Chinese porcelain was fashioned. Some time later at Aue, near Meissen Castle, a large supply of genuine kaolin was discovered, and the King of Poland, then one of the Electors of Saxony, founded pottery works there. This was the beginning of the world-famous Dresden china. But the king was quite as secretive about his china-making as was everybody else. His workmen were held captive in the castle, and all the clay stored for use was packed in barrels by deaf and dumb servants. At first the ware was made



TOP: ROW. THE FLOWER VENDERS. BOTTOM: WEDGWOOD. JASPER VASES only in blue and white, but gradually it came to be decorated with the many-hued flowers which we now see upon it.

In France the discovery of kaolin was also accidental. In 1768 the wife of a doctor by the name of Darnet, who lived not far from Limoges, was pulling weeds in her garden when she chanced to pull up one with quantities of fine white soil clinging to its roots. Thinking this white powder might be useful for making soap, she took it home and showed it to her husband. He was so curious about it that he took it to a chemist, who in turn carried it to the head chemist at the Royal Porcelain Works. Instantly it was pronounced to be kaolin, and in December, 1769, a number of pieces of porcelain made from the new clay were presented to the king. Thus began the making of china at Limoges.

THE FAMOUS SEVRES, DOULTON, AND WEDGWOOD WARE

Some years ago an American named Haviland invested a fortune in the pottery works at Limoges, from which have come to America quantities of beautiful china of French manufacture which have taken the place of our early American stone china with its historic pictures, as well as our wares of later make. Thus far we are still unable to turn out china as fine as that of foreign manufacture. We must thank France, too, for that rare and delicate Sevres china, not made since 1804, and now so valuable.

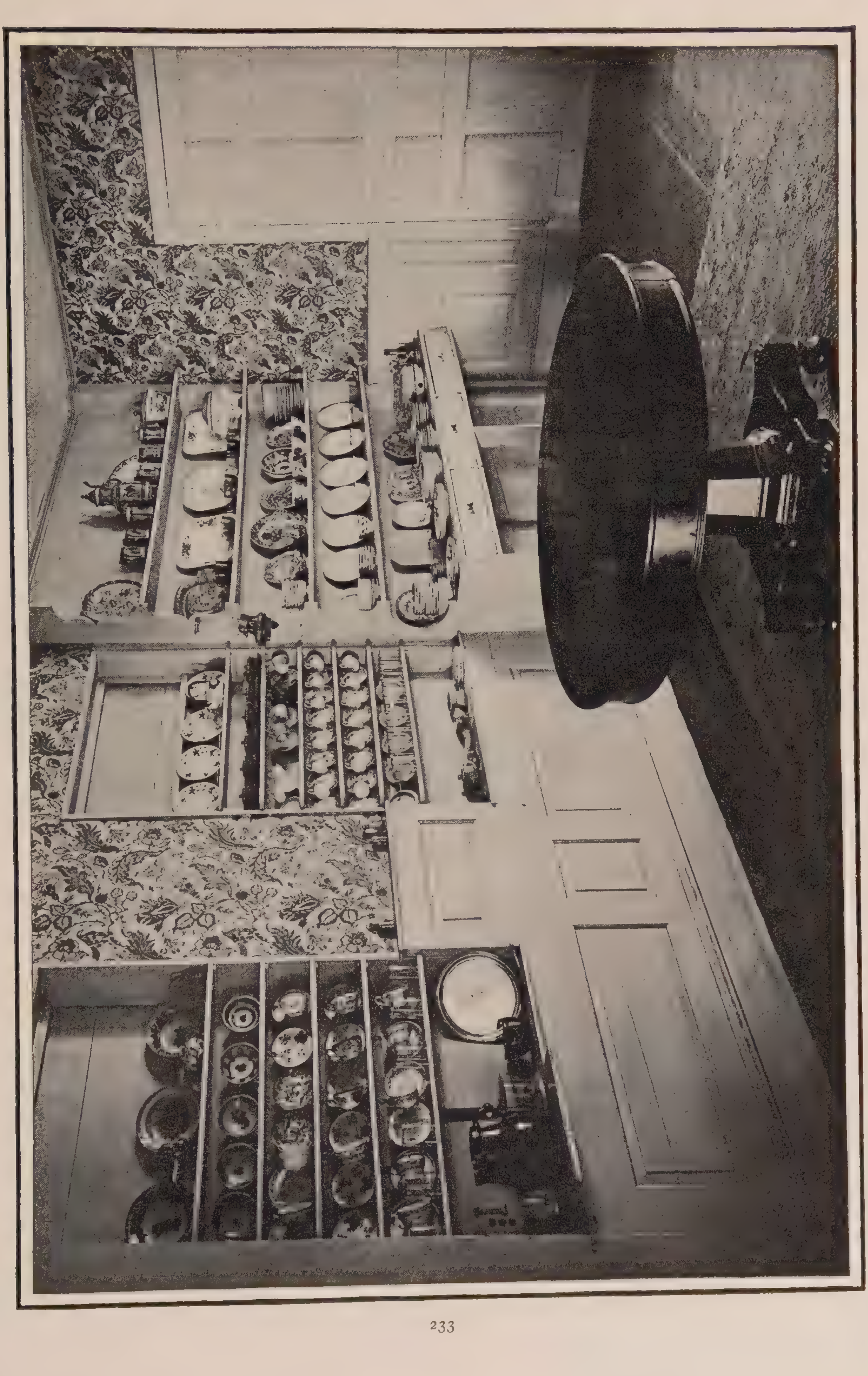
Many other celebrated china-makers have come down to us through history: Henry Doulton, renowned not only for the beautiful ware bearing his name, but also for his discovery of glazing drain-pipes which revolutionized sanitation; Wedgwood, the English potter, who first fashioned that unique china adorned with classic figures standing out with cameo-like delicacy against a background of dull green, blue, brown, yellow, or violet. Royal Worcester, Crown Derby, Copenhagen, Cantagali—almost all the great nations have furnished their own distinctively decorated wares. Those who have made a study of china can readily tell the history of the rarer pieces from the mark upon the back.

HOW CHINA IS MADE

The making of china is dependent upon two factors, the body and the glaze. The body must be made of carefully selected clay from which all impurities have been removed. This clay is a blend of kaolin (china clay) and blue (or ball) clay. The finer the grade of china the more kaolin is put in. Kaolin makes a thin clay, resulting in a very delicate china. Ball clay is more plastic and therefore stronger and less sensitive to changes of temperature. These clays are cleansed by mixing them with water; as they are lighter than any impurities blended with them, the clay rises to the surface of the water and may easily be drained off. There must also be put with this clay a certain proportion of glass-forming material—a finely crushed granite containing partially decomposed felspar. This agent is put into the glaze as well. Then we must have a specific amount of oxide of silicon or flint, which serves to prevent the contraction of the material and lends whiteness to it. To these ingredients is added oxide of cobalt, a deep blue mineral, not affected by heat. Like the felspar and flint, this cobalt must be finely powdered and sifted through gauze or closely meshed wire; otherwise the china will be specked with blue, as is so much of the very cheap ware.

After these materials have been mixed together and pressed through fine cloth, powerful magnets are applied to extract every particle of iron or other metal, as the presence of any mineral matter would be apparent after firing. The clay is then thoroughly kneaded by machinery and turned over to the potter, to be shaped by hand on the potter's wheel, turned on a turning-lathe, or molded by machinery.

Thrown ware, or that fashioned on the potter's wheel, is of more choice design and less liable to be duplicated than other china, since each piece is given individual attention. Both thrown and turned ware are also stronger, better made, and hence more expensive than machine-made wares. Since, however, we now demand hundreds of pieces of a kind, it is impossible to make it all by this slower and more costly method, and much of it must of necessity be made by machinery.



A GOOD COLLECTION OF OLD CHINA

ROPE, AND HOW IT IS MADE

NO one knows how many years ago it was that man first made use of the first crude ropes. Long before the dawn of history, primitive man undoubtedly used strips of hide or of bark in his daily occupations. He may even have employed fibrous roots or the flexible reeds which grew by the shores of stream or marsh. As the need for longer and stronger lines developed, it is probable that a number of these fibers, or even the coarse hairs of animals, were twisted together to form a cord or rope.

It is known that the Chinese were among the earliest of the ropemakers, and that the savage tribes of various parts of the world were also accomplished in the art. In Egypt, ropes manufactured from papyrus have been found in ancient tombs, some of them dating back at least 3500 years. The Greeks and Romans are also known to have used ropes several hundred years before Christ. Our own American Indians were among the early peoples whose ropemaking is a matter of history.

The modern method of making rope is an elaborate process, and is an industry which draws on many corners of the earth for its raw materials. Hemp, flax, and Manila fiber are the most commonly used, while jute and cotton find application to a limited extent in the production of special types of rope. Other ropes are made from wires of steel or other metal. Hundreds of kinds of cord and twine are also manufactured for industrial and household uses. Everywhere you turn you will see one of the manifold ways in which these cords are employed. Consider the varied applications of rope, twine, and cord with which you meet in a day's work and play, and you will begin to form a picture of the high standing of the ropemaking industry in our plan of civilization. Because of limited space, we must limit ourselves to a description of the manufacture of fiber ropes.

Although Kentucky and California furnish a limited supply of American hemp, the Philippines, Russia, Italy, and New Zealand provide most of the fiber consumed by American manufacture. Java, Africa, the Bahamas, Yucatan, Mexico, and Cuba also provide certain types of fiber for the ropemaker's use.

DRYING THE FIBER, PHILIPPINE ISLANDS

WHAT HEMP IS — WHERE IT GROWS

Hemp comes from the fibrous portion of the stems of plants. If a fine fiber is desired, the plant is pulled up as soon as it has blossomed; if coarser fiber is required, the hemp is allowed to grow until it has matured. The hemp plant grown for fiber production has a straight stalk usually growing from five to eight feet high. While true hemp comes only from this plant, the fibers of many plants are commonly known by the same name.

In commerce the fiber takes its name from the country in which it was grown, as Russian hemp, Italian hemp, Manila hemp, and American hemp. The character of the plant and its fibers differs according to the conditions of the climate and soil in which it was produced. Manila hemp is far more widely used than any other. Italian hemp is finer, lighter colored, and stronger than American or Russian, and commands a higher price. With the exception of Manila, all these various hemps are a bast fiber—that is, they are obtained from the bark of the plant. The hemp is cut, spread out to dry, and then gathered and stacked in bundles. After a time these stacks are opened and the hemp is again spread out for exposure to dew, frost, and sun; during this rotting process the gums holding the filaments together rot, and the dry, inner, woody part of the stems breaks and falls off, leaving the fibrous strips or bands in such condition that they can readily be cleaned, bunched, and pressed into bales. American hemp is marketed chiefly for tarred goods.

INTERIOR OF NATIVE ROPE FACTORY, PHILIPPINE ISLANDS

Coir, another material used for making brown, tarred rope, comes from the fibrous bark of the cocoanut. Still another fiber employed in rope-making, and one ranking next in importance to Manila hemp, is sisal, which we get from the leaves of the Mexican cactus.

HOW SISAL GROWS AND IS PREPARED

Sisal plants are grown on large plantations known as "haciendas." The small shoots are set out in rows and weeded about twice a year. At the end of five years the first crop of long, swordlike leaves which mature at the base of the plant is ready to be cut, and from this time on until the cactus is twenty years old it continues to yield leaves for manufacture. At cutting time, natives armed with "corbas," or knives, go through the fields lopping off the long, prickly growth; the thorns are then trimmed from the edges and ends, and the leaves, tied in bundles of fifty each, are carried to the cleaning mill. Here the pulp is scraped from the fiber by powerful cleaning machines, and the fiber, after being dried in the sun, is pressed in 350-pound bales ready for shipping.

Since Manila and sisal are so much used, it is interesting to note that while Manila fiber ranges from six to ten feet in length, sisal measures from but two to four feet. The latter possesses only three fourths of the tensile strength of the former. Manila is famous for its smoothness and pliability; sisal is without flexibility and is much more stiff and harsh. This accounts for the unpleasant "splinters" found in sisal rope; their appearance in so-called Manila rope shows the use of sisal as an adulterant. Sisal is also more easily injured by exposure to moisture and varying atmospheric conditions. Sisal rope may be tarred, however, for out-of-door purposes, and the twine is in great demand for tying grain sacks and bales of cloth, and as a binder twine for the self-binding reapers now employed in grain-raising regions.

MANILA HEMP

For the ropemaker the most desirable raw material is "Manila hemp," which is really not hemp at all, but a fiber obtained from the wild banana plant of the Philippine Islands. This fiber is contained in the outer bark of the separate leaf stems, their inner portions being of a soft pulpy nature. After the stalk is cut the native peels off strips of this fibrous bark. After stripping the outer layer of stems, he scrapes off its remaining pulp and proceeds to strip the next inner layer. The fiber from the inner layers is finer and whiter than that from the outer. The fibrous strips are then cleaned by drawing them under a knife hinged over a block of wood.

After it is scraped the fiber is hung over bamboo poles to dry. When thoroughly dried it is tied up in hanks and carried to market. In the warehouses of the exporter it is sorted and graded, packed into bales, and shipped.

In consequence of varying conditions of climate and soil the hemp differs greatly in strength, texture, length, and color. Hence all shipments must be regraded before using. Frequently there are as many as seventy-five varieties in a single consignment, and this work must therefore be done by expert judges. After the fiber is sorted it is weighed, re-baled by a compressed-air engine, and marked and stored for future use. When taken out to be spun it is usually oiled to give it gloss and strength, and then combed so that its fibers will lie side by side. The hanks of fiber, somewhat matted from the oiling, are fed by hand into the first breaking machine, which turns them out in sliver form. This sliver is then reduced by other machines to the size required for spinning.

CUTTING SISAL LEAVES

LOADING SISAL LEAVES ON CAR

TARRED ROPE AND THE ROPE WALK

Tarred rope, associated in our minds almost entirely with shipping, is in reality turned to many other purposes. Lath yarn, in vast quantities, is annually consumed by the lumber industry. (See "Lumber.") Pine tar, best suited for cordage, comes from distilling in a tar kiln the pitch from the pines of northern Europe, or the long-leaf, yellow, or Georgia pines of the United States, found along the coast from North Carolina to Texas. When the tar comes from the kiln it is caught in a hole dug beneath the outlet, and is dipped up and poured into barrels. To penetrate and adhere to the yarn the tar must be heated to 200 degrees or over. The tarring is done in long, copper-lined troughs, where the temperature can be regulated by steam pipes. As the yarns, heavily saturated with tar, come

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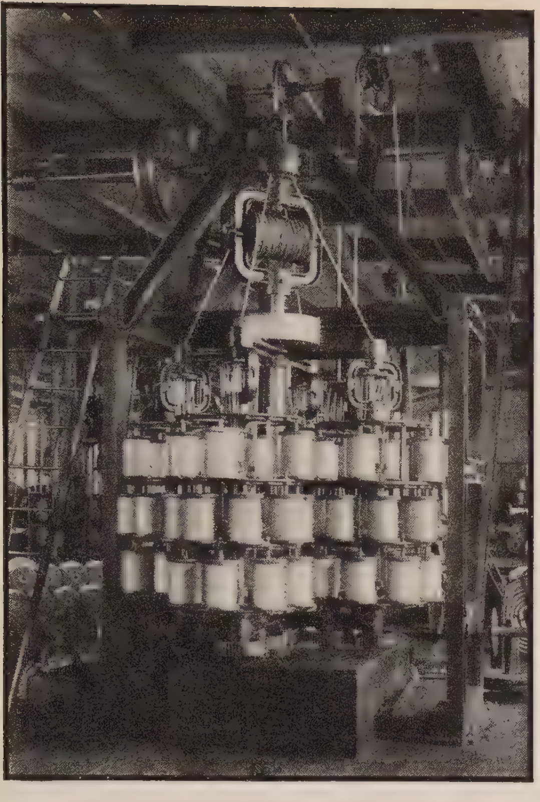

FOUR-STRAND COMPOUND LAYING MACHINE

from the "copper," they are compressed between two rollers, adjusted to leave in them as much or as little tar as is needed for the particular goods being made. The pull which carries them through the tar and the rollers comes from the drums around which the yarns travel preparatory to being reeled on friction-driven receiving bobbins.

In making tarred rope in all but the smaller sizes, the rope walk has certain advantages not offered by newer methods. It also provides efficient equipment for turning out the largest ropes, which would otherwise require special machinery. If you can get a chance to see this kind of rope-making you will have an interesting time watching the twisting of the strands, as well as the man who follows the machine and gives the name, the "rope walk."

Within the factory two methods of rope-making are employed: that in which the strands are formed on one type of machine and twisted into rope on another, and that in which both operations are performed on a single machine. Modern rope-making ingenuity, however, reaches its high-water mark in the compound laying machine, where the two operations of forming the strands and laying them into rope are combined; but since this machine must be stopped each time the supply of yarn on any bobbin is low, it would be impracticable for making the larger ropes.

Therefore, we see that by means of modern inventions rope-making has been transformed from a laborious task, dependent for its success on the skill of the individual expert, into a quick, sure operation where every problem is met with the unfailing accuracy of a perfect machine. The work is done more scientifically and more uniformly than it was in the days when it was strictly a hand process. When we consider the great amount of cordage required by the civilized world in the form of twine, cord, rope, hawser, or cable, the importance of this industry is apparent.

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MEXICAN ROPE-MAKING

PAINTS AND THEIR USES

PAINTING is one of the oldest as well as one of the newest arts. Early in the business of building their houses, bridges, and boats, men discovered that a surface covering of some oily liquid which would harden into a smooth outer coating would protect their handiwork from the ravages of sun, wind and rain. Noah covered his ark with pitch and from that day to this men have painted the things they wish to preserve.

Paint beautifies as well as protects. Both outside and inside our houses we use paints, enamels and varnishes to improve the appearance of walls, trim, floors — even our furniture. When we grow tired of living amid "the same old surroundings" nothing will do half so much to bring a sense of change as will a fresh, clean, bright coat of paint of either the same or a different color. Our automobiles, too, are not only protected but beautified by their coats of gleaming lacquer or enamel. In fact, so many and so different are the uses of paint that one large company is said to offer a variety of nearly five thousand different shades and types, each of which has some special use.

HOW ARE PAINTS MADE?

Our first thought of paint is of color. "What color shall we paint our house?" is the question asked at the family table, and long are the discussions of the relative merits of gray, white, yellow, or brown. It is only the father of the family who is thinking of the way that the paint will preserve the wood and so lengthen the life of the house. The obvious effect of paint is to give color to the surface on which it is placed.

Paints in ancient times were chiefly in natural colors. The Greeks, Romans, Assyrians, and Egyptians used the earth colors, reds from iron oxides, yellow ochers, mineral blues, and tints from lead and copper ores. Since oil was not so easily available then as it is in modern times, they found white of egg, or egg yolk, or some similar substance a convenient vehicle for carrying the color which they wished to spread on their outer and inner walls. The beautiful colorings on the walls of the houses of Pompeii and in the temples of Greece, Egypt, and the Orient testify to the skill of the artists who mixed the paints which have survived for so many hundreds of years.

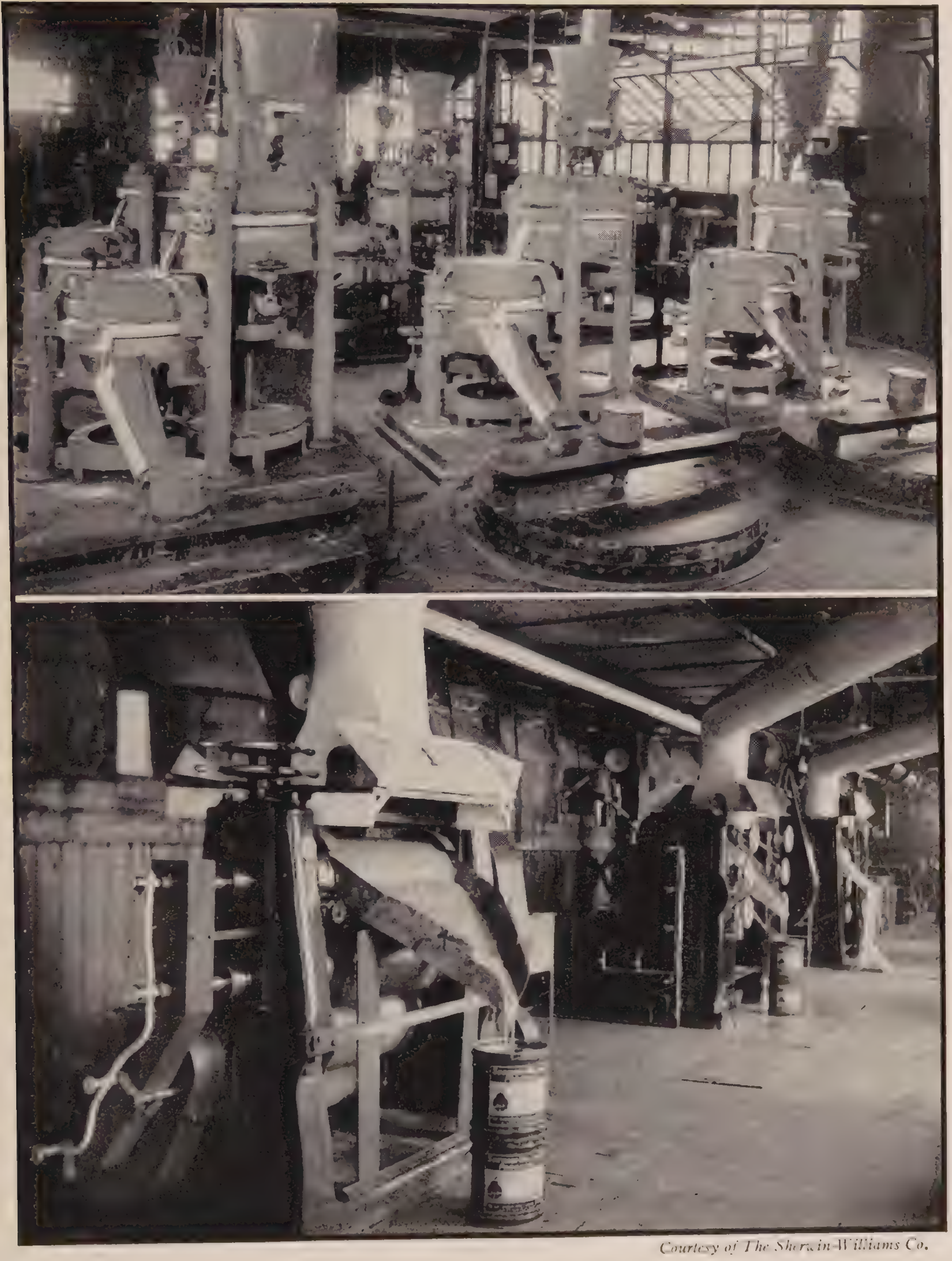
"Prepared paints," as the dealers call them, are so popular nowadays that most of us have at some time opened a can of some shade of paint and gained some experience, as we used it, in the variety of kinds of paint and the "texture," so-called, of the different mixtures. All paints are made up of a liquid, called the "vehicle," and a coloring substance, called the "pigment." Since dry color powder could not be applied to a surface, the liquid gains its name of vehicle because it carries within it the color. In this particular it differs from a dye or a stain, both of which are color mixtures which are absorbed by the particles of the wood or cloth to which they are administered, so that they really enter into the material to which they are applied. Paints and varnishes are coverings, the only requirement being that they have enough adhesive liquid to hold them to the surface for which they are to form a coating.

To the mixture of liquid and coloring matter is often added some liquid which will thin the mixture, and also a "drier" which will speed up the process of forming from the thin, sticky substance a firm, hard coating.

MIXING PAINTS

Most of our paints are oil paints. In these the vehicle is linseed oil, made from compressed flax seed, or some similar vegetable oil such as those obtained from soya beans, perilla seeds, and tung nuts. With the oil vehicle are mixed white lead, zinc oxide, and a comparatively new pigment called titanium dioxide which has very high covering power and is exceptionally white. The coloring matter may be the natural mineral colors, such as the various forms of iron oxide, which differ only slightly from those used in ancient times. However, many brilliant and beautiful pigments are now obtained from coal tar by complex chemical processes. Since the paint must be fluid enough to spread easily, turpentine or some similar thinning liquid is added. For quick drying, special drying compounds are also included.

In the old days all this mixing was done by hand, and a good painter would spend many



Courtesy of The Sherwin-Williams Co.

GRINDING PAINT PIGMENTS

Top: Grinding mills of the older mill stone type. Bottom: The newer roller type grinding mills which reduce the pigment particles to extremely fine size.

hours working over his paints to obtain just the right constituency and shade for the surface which he was to cover. The skill and good judgment of the painter are still important factors, but his labors are much simplified by the work that has been done for him in the factory. Here the oil and pigment are placed in a mixer and mechanically stirred for hours, so that the parts are perfectly blended. From the mixer they go to the grinder, where two huge mill-stones, revolving in opposite directions, smooth out every particle that might roughen the paint. Then the thinner and drier are added in carefully measured amounts according to the needs of each kind of paint, and lastly, if this is to be an enamel paint, varnish is added.

HOW DOES VARNISH DIFFER FROM PAINT?

Varnish is a transparent liquid. The grain of a hardwood floor will show through a coat of varnish, where a coat of paint would hide it entirely. Yet varnish is thicker and stickier than paint for it is made from a gum mixed with oil and therefore, when it hardens, gives a more shiny and brittle surface. We have all seen the drops of yellow resin or gum on a pine tree. Some varnishes are made from this pine resin, but they are of a cheap grade which grows sticky when exposed to heat. The best gums come from New Zealand and Africa where the natives dig them from the ground. They, too, are the hardened sap from trees, but they are hundreds and thousands of years old, the sap from forests long gone. Synthetic resins or gums, obtained chemically from various raw materials such as glycerine and coal tar, are also used and have proved even more durable than the natural gums.

Varnish making is even more difficult than paint making as the oil and the gums have to be heated separately and then mixed at exactly the right temperatures and cooked again over a very hot fire before the turpentine is added for thinning. Instead of the grinding process through which paint is put, varnishes must be filtered through hundreds of filter papers until they are thoroughly cleaned and strained of all impurities. Even then the mixture is not at its best but will improve with age.

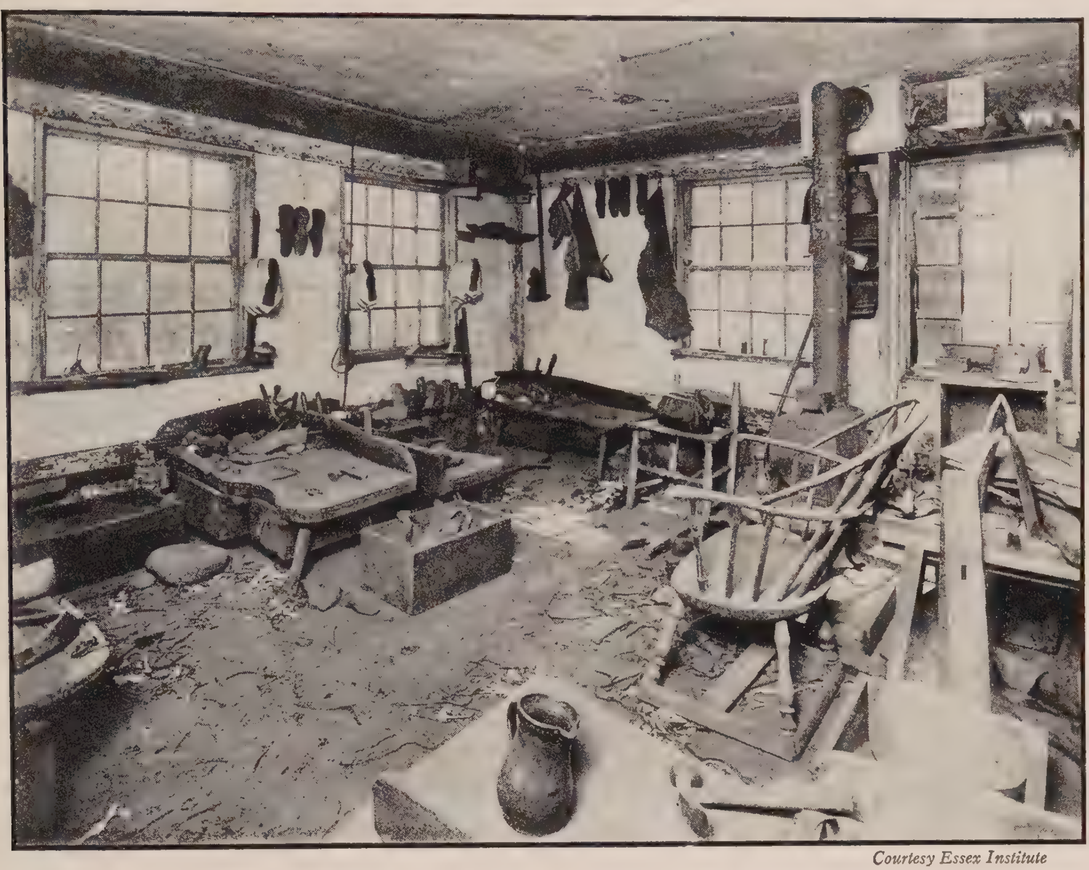
Akin to varnishes, but with an alcohol or turpentine base instead of oil, are the lacquers which are so much used in the automobile industry. Lacquers had always given a pretty coating, but the film had been so thin that it was brittle and short-lived. By much experimenting the chemist has succeeded in producing a lacquer for metals giving brilliancy and gloss with a good amount of durability. Cars are now sprayed with these lacquers and thus given the fine finish with which we are familiar.

LUMINOUS PAINTS

Radium and radioactive substances have introduced a new element into paints, making it possible for the instrument maker to coat his dials with a covering which will be self-lighting by night as well as light-reflecting by day. The convenience of this in the "radiolite" watch-face is obvious. Its real service comes on the instrument board of an airplane where flying by night would be dangerous without constant visibility of all dials. With a self-lighting set of dials the aviator can be sure that he will always be able to read his instruments; whereas an electric lighting system might fail in an emergency. Zinc sulphide is one of the ingredients in these luminous paints.

WATER-MIXED PAINTS

The earliest type of water-mixed paint was the simple whitewash, a mixture of slaked lime and water, used by our forefathers to whiten walls and fences. Calcimine, as used on ceilings today, is essentially whitewash to which some glue and perhaps coloring matter have been added. The glue gives the mixture body and helps to hold it to the plaster. Whitewash and calcimines give little protection and are not washable. Casein paint, sometimes called cold-water paint, is a decided improvement over the earlier water-mixed paints. Casein, a white protein obtained from milk, is mixed with paint pigments and the mixture sold as a powder or paste. When the powder or paste is dissolved in water and applied to a wall a chemical change gradually takes place so that after a few weeks the casein is no longer water soluble and the painted surface can be sponged to remove soiled spots. Still another type of cold-water paint uses a synthetic resin instead of casein.



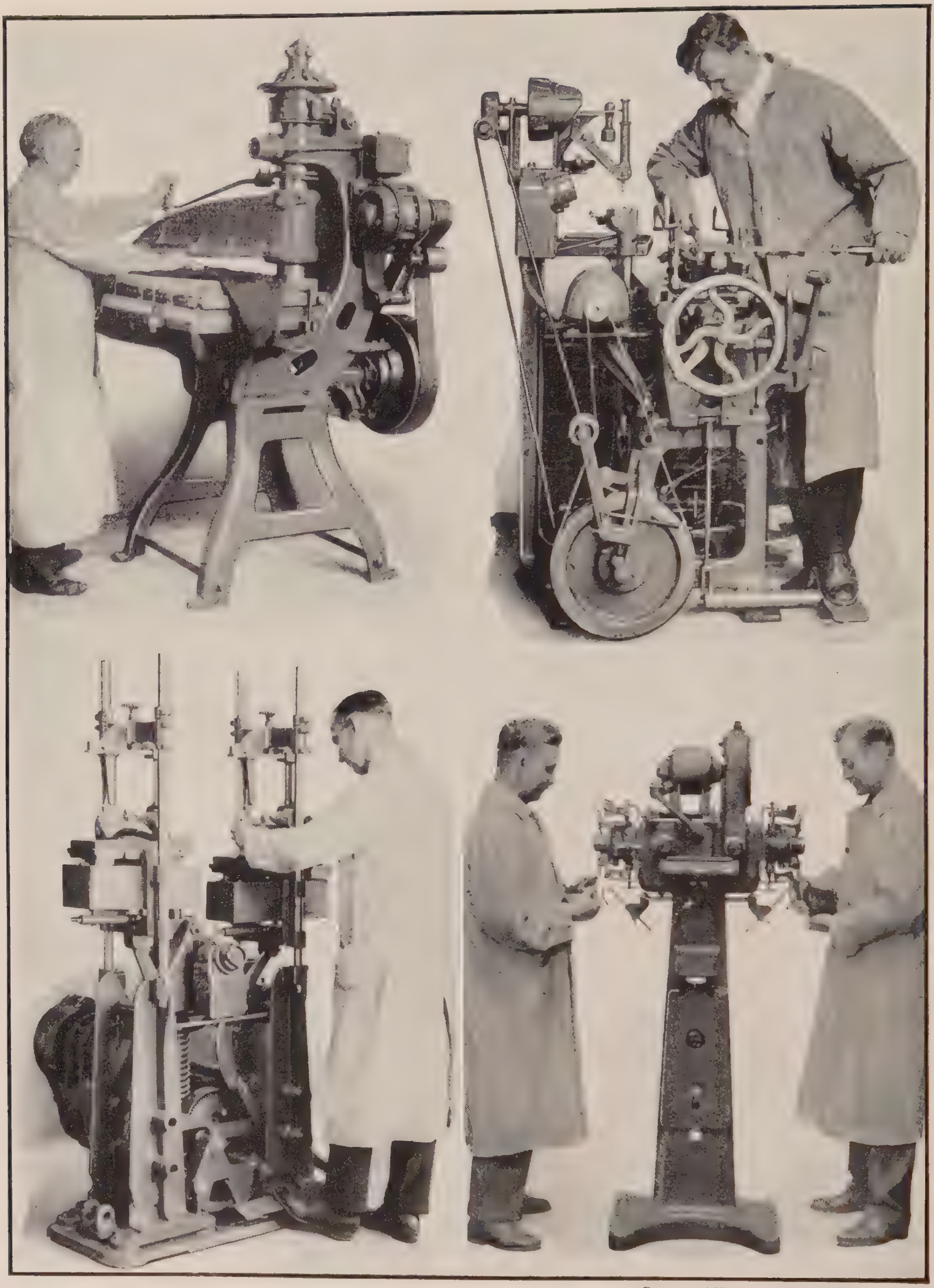
Courtesy Essex Institute

A SHOEMAKER'S SHOP OF THE YEAR 1800

SHOES

COVERINGS for the feet were early recognized even by savage tribes as an essential to comfort. In some countries footgear originated in need of protection against burning sands or scorching stones; in other lands the cry was against cold or rough forest paths. Wood, fiber, or, best of all, leather, which the hunter or herdsman could make from the skin of animals, must be fitted to the shape of the foot in a way that would make for comfort and protection for the sole of the foot. The Indian fashioned his deerskin moccasins, decorating them with beads and porcupine quills; the Turk and Arab made gold-embroidered slippers of colored leather; the Chinese and Japanese had shoes of straw or satin; the Dutch wore wooden sabots; and the Eskimo fashioned fur-lined boots. There were heelless sandals; shoes with long, narrow toes which curved upward; shoes with jeweled or vermilion heels. Slowly from out this Babel of crude models was evolved the present-day shoe, which has proved to be the footwear best adapted to the conditions of life and climate in which most of us dwell; but in far-away lands Orientals still cling, as we hope they will long continue to do, to their gold-embossed slippers and the Eskimo to his fur-lined boots.

There was a time, and it is not long past either, when cobblers at tiny benches laboriously made by hand all the shoes required by the civilized nations of the world. But like many another industry, machinery crowded out one part of the trade after another, and presently the old-fashioned shoemaker and his bench were displaced altogether. The making of shoes by machinery was a boon to mankind, for in a few hours more shoes could



Courtesy of United Shoe Machinery Corp.

UPPER LEFT: CUTTING LEATHER AND LINING FOR UPPER PART OF SHOE. UPPER RIGHT: SHAPING UPPER PARTS OF SHOE OVER A FORM CALLED A "LAST". LOWER LEFT: CEMENTING SOLE TO UPPER PREPARATORY TO SEWING. LOWER RIGHT: FINISHING EDGE OF SOLE.

be turned out by these almost human devices than any hard-working shoemaker could finish in a year. In consequence of the new industrial conditions cheaper and better shoes came into the market — shoes far more comfortable, and representing the best thought of many minds.

HOW LEATHER IS PREPARED

Hides and skins are the raw materials from which leather is manufactured. Generally speaking, a "hide" is the covering of one of the larger animals such as a horse or a steer; a "skin" is derived from one of the smaller creatures like a calf, a goat, or a sheep. Hides, because of their thickness, are usually made into sole or other heavy leather. From the smaller and thinner skins comes the leather used in making bags, gloves, or the uppers for shoes. American tanneries secure their hides from both foreign and domestic sources, the principal imports coming from South America, with South Africa and Australia also contributing a small number each year.

Before the skin of any animal can be used as leather the hair, fur, or wool upon it must be removed, and the skin preserved so that it will not decay. This process is called "tanning." When skins are received at the factories they are always thoroughly salted to keep them from spoiling. Sometimes they are "green-salted," which means that they are salted and shipped as soon as stripped from the animal; sometimes they are "dry-hides," or dried without being salted, and as a result arrive at the tanneries stiff and hard; sometimes they are "dry-salted," or salted when freshly taken off, and then allowed to dry. All these skins, however, in no matter what condition, must be soaked in borax and water to cleanse and soften them.

Afterward they are thoroughly cleaned by hand, and all parts of them not useful for leather-making are taken off. This done, the hides are plunged into a bath of lime, sulphide of sodium, red arsenic, and hot water, which mixture loosens the hair so that it can easily be taken off. Sheepskins are not immersed in this bath because of the injury to the wool upon them; instead, the liquids are applied to the inside of the pelts, after which the wool can be pulled off without being wet. Such wool is called "pulled wool," and is sold to woolen mills.

The "slat," or prepared skin, if heavy, is next split into two layers, and is then limed, after which the lime is washed out and the skin is "pickled" in a solution of salt, sulphuric acid, and water. Next comes the tanning, to give the hide strength and color. Two processes are used. The skins are either soaked in a vegetable liquid of water mixed with oak, hemlock, chestnut bark, sumac, palmetto roots, or quebracho, or are tanned with a blend of chemicals or "chromates." The process used depends upon the purpose and quality of the skin.

CUTTING OUT THE SHOES

The leather is now ready for use, and the uppers for the shoes are cut out on a "clicking machine," which not only turns out the leather in the necessary shape but also marks the location for the tip and, if desired, the "foxings." The edges of the material which are to show when the shoe is done are beveled off by a "skiving" machine, while a different machine stamps out the perforated tips in any pattern wished. Upon a tag accompanying the leather is a schedule of the size, variety of material, kind of lining, stays, and style of the shoe, and this tag goes to the clicking machine, so that when the cut-out leather travels on to be sewed it has with it all linings and necessary parts for the finished article.

Stitchers then set about uniting these various parts of the upper, using wonderfully complex sewing machines, which do many different things at once. Holes for the eyelets are spaced exactly opposite each other, punched, and the eyelets put in by an eyeletting machine.

The best eyelets are of solid color on top and are clinched inside the shoe with metal; an eyelet made with a metal finish soon turns brassy and cannot be remedied unless replaced by one of the "fast color" variety. When all this has been done, the shoe-upper, with its tag, is sent on to the bottoming room, there to await the coming of the sole-leather parts which have, in the meantime, been made for it.

HOW THE SOLE IS PUT ON

These parts are the outsoles, insoles, counters, toe-boxes, and heels — many parts, you see, to keep track of and make to fit correctly. Sole leather is usually tanned with bark and is heavy and strong. The soles are first roughly cut from the big "sides" of leather by dieing-out machines, but afterward must be rounded off to conform to the required pattern for the sole. Then this outsole is passed through heavy rollers that compress the fibers of the material so that it will wear well. Next, the outsole goes to a splitting machine, which pares off the sole to a uniform thickness. While all this is being done, the insole is receiving something of the same general treatment, and in addition a channeling machine cuts a slit along its edge, thereby forming a lip which, when turned up, guides the operator who is welting on the shoe. The heels are formed from many layers of leather cut in the proper size and shape, cemented together, and pressed down firmly by machinery. The counters for holding up the heel, and the toe-boxes, or stiffening, to be placed between the toe-cap and the vamp, are also prepared and sent on with the soles to the room where the shoe-upper is awaiting them.

If the shoe is a laced one, strong twine is passed through its eyelets so that it may be held in its natural position while it is being finished. Now the parts of the shoe are ready to be put together. The toe-box is placed in position to give form to the toe; the counter is put in to hold up the heel; and the upper is drawn over the last. To the bottom of this last the insole has already been tacked.

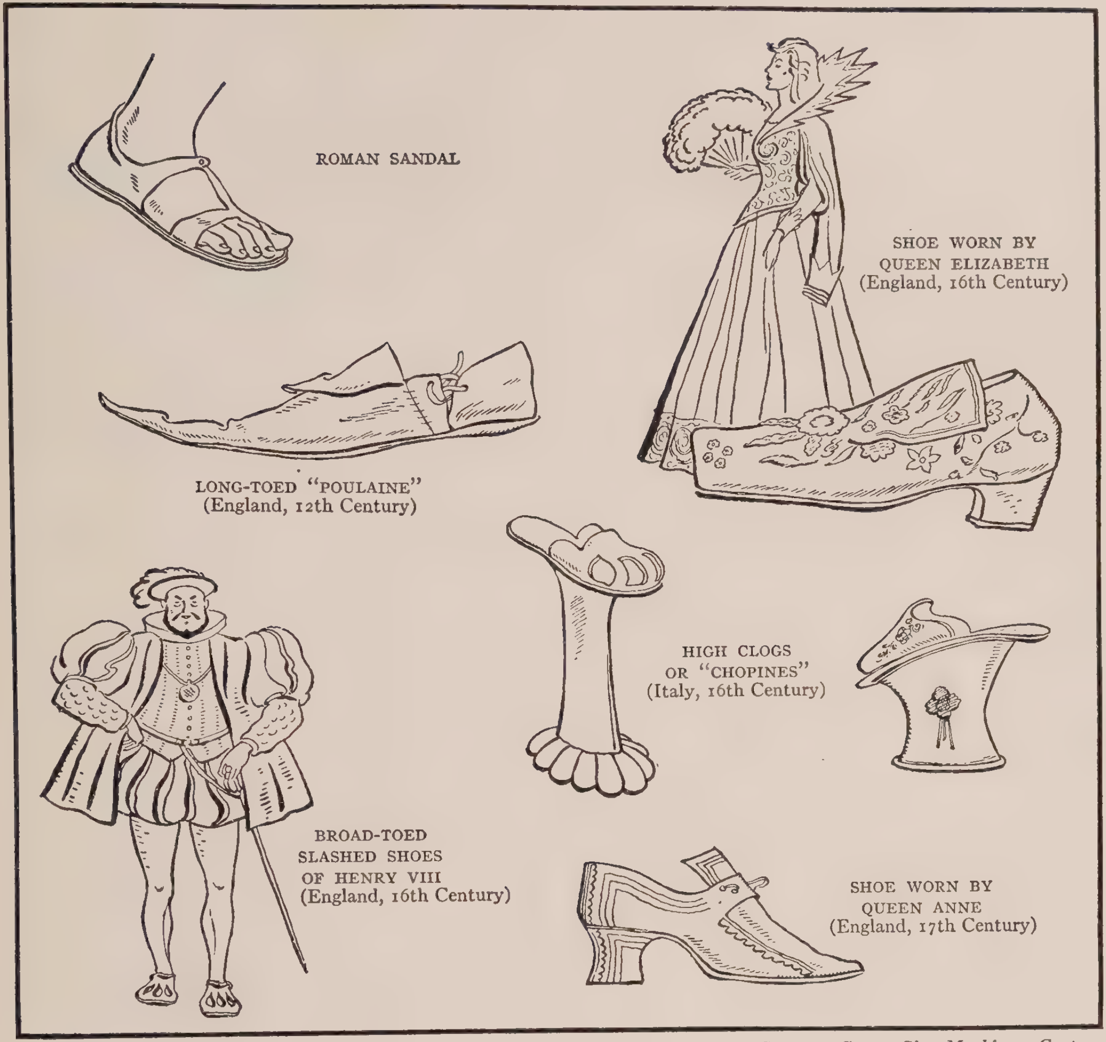
The last is a very important factor in shoemaking, since upon its shape depends the shape and size of the finished shoe. A workman puts the upper on the last and after seeing that the seam at the heel is in the right place presents it to a machine which drives two tacks which hold it securely in place at that point. He then hands it on to the operator at the pulling-over machine. This machine plays a vital part in the process, for it is the one that draws the forepart of the shoe upper down to the last and enables the operator to quickly adjust every seam to its correct position on the last, and the secondary motion of the machine drives five or seven tacks, as may be required, to hold it in place.

The lasting machine now draws the shoe upper and lining evenly and tightly around the edge of the last, simultaneously driving tacks to hold them in place. If it is a Goodyear welt shoe, these tacks in the forepart of the shoe are driven but part way in so that they may be afterwards removed. A little trimming machine then cuts away any surplus material.

The welt, which is a narrow strip of leather, is sewed around the edge beginning where the heel is placed on one side and ending at the same spot on the opposite side. The needle on this machine works on the arc of a circle and does not go inside the shoe but in the between substance of the insole, and unites the insole and the shoe upper and lining through this means. A machine trims off the surplus part of the welt smoothly and accurately down to the stitches, all the tacks in the forepart of the shoe are withdrawn, and the welt is beaten out so that it stands out evenly from the edge of the shoe.

The shank piece, which gives permanent form to the curve of the sole, is tacked in place and a layer of ground cork and rubber cement is added to make up the difference in height occasioned by the addition of the welt. The surface of the welt and filler are then coated with rubber cement, as well as the flesh side of the outsole, and both are pressed securely together by a machine for that purpose. The welt and outsole are then rounded or trimmed so that they bear proper relation to the shape of the shoe and the welt is stitched to the outsole by a machine which makes a secure lockstitch. It is in this ingenious manner that shoes are made which are perfectly smooth inside.

The shoe is then placed on the jack of a heeling machine and all the nails are driven at one time. Then follows a long series of trimming, buffing, and polishing operations, varying with the quality of the shoe produced and the ideas of different manufacturers. In making some shoes, as high as 210 operations are required after the order is received in the factory, 174 of which may be performed by machine and 154 by different machines.


ROMAN SANDAL
SHOE WORN BY QUEEN ELIZABETH (England, 16th Century)
LONG-TOED "POULAINE" (England, 12th Century)
HIGH CLOGS OR "CHOPINES" (Italy, 16th Century)
BROAD-TOED SLASHED SHOES OF HENRY VIII (England, 16th Century)
SHOE WORN BY QUEEN ANNE (England, 17th Century)

Courtesy, Compo Shoe Machinery Corp.

SHOES OF OLDEN TIMES

SHOES WITH CEMENTED SOLES

Stitching was the only method of attaching the sole to the upper until about the year 1928. At that time a method of cementing, rather than sewing, the sole to the upper was developed as a result of experiments by William H. Bresnahan and Barnard S. Solar, shoemakers of Boston. Their first experiments were not entirely successful due to the lack of a proper adhesive. Their process called for a cement that would not only hold the sole firmly in place but would be flexible and resilient. However, American research laboratories soon developed the cement desired and, as a result, more than half of all women's dress shoes are today made by this process, known as the "Compo" process.

Thanks to modern manufacturing methods, the shoes we wear today are lighter and more comfortable than ever before, yet they are also stronger and more serviceable. The shoemaker of today finds that his modern machinery allows him to get all sorts of effects in design and pattern that were once impossible or else very expensive, and he can produce them on a volume basis at prices within the reach of all.

FLOCK OF SHEEP, EASTERN SLOPE OF THE CASCADE MOUNTAINS, WASCO, OREGON

WHERE DO WE GET WOOL?[1]

HOW many of us realize, when bundled into our warm winter woolens, the varied and interesting journey the wool has traveled before it has reached us? What do we know of the perils of growing wool, or of the great woolen mills where the wool is made into finished cloth?

Wool growing is one of the largest industries of the United States and Canada. The ten leading states engaged in this industry in order of the quantity of sheep they foster are: Texas, California, Wyoming, Montana, Utah, New Mexico, Oregon, Ohio, Idaho, and Colorado.

Free grass on the western ranges as well as the healthiness of the flocks are the factors which have led to sheep-raising in certain localities. New Mexico is the oldest center for "sheeping." Here great herds dot the high plateaus, and are fed on the rich grass thriving there. The sheep-owners make corrals of cedar into which they drive their flocks at night that they may be sheltered from coyotes, or prairie wolves.

In other states sheep are raised on big ranches, kept in vast inclosures, and fed with alfalfa hay, grain, rape, kale, corn, and pumpkins. Colorado often fattens her sheep on Canadian peas, which grow readily in the soil. Still other states turn their flocks free on the ranges and throughout the year trail from low to high ground in search of food.

`SHEEPING ON THE RANGES

"Sheeping on the ranges" is a most picturesque industry. As soon as the herds are sheared in April all the sheep in the flock are dipped. This process takes place after the shearing, because at that time the wool is closely cropped and will most easily dry. Some owners dip their sheep twice a year. Dipping prevents "scab" — a disease common to sheep, and one which if allowed to gain headway will infect an entire band, causing the wool to peel off in great patches. Dipping also prevents ticks and diseases of the eyes.

HOW SHEEP ARE DIPPED

A long, narrow trough just wide enough so the sheep cannot turn is used for dipping. This trough is often made of cement or concrete, and has an incline at one end down which the sheep are hurried. At the other end of the trough is a draining platform. Various solutions are used for the dip — mixtures of coal-tar, sulphur, or lime; but whatever the solution, it must be hot to be of value. The sheep are walked down the incline and then, plunging into the trough, they swim their way to the other

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[1] The material for this article is taken from "The Story of Wool," by Sara Ware Bassett, and is republished through the courtesy of the Penn Publishing Company of Philadelphia.

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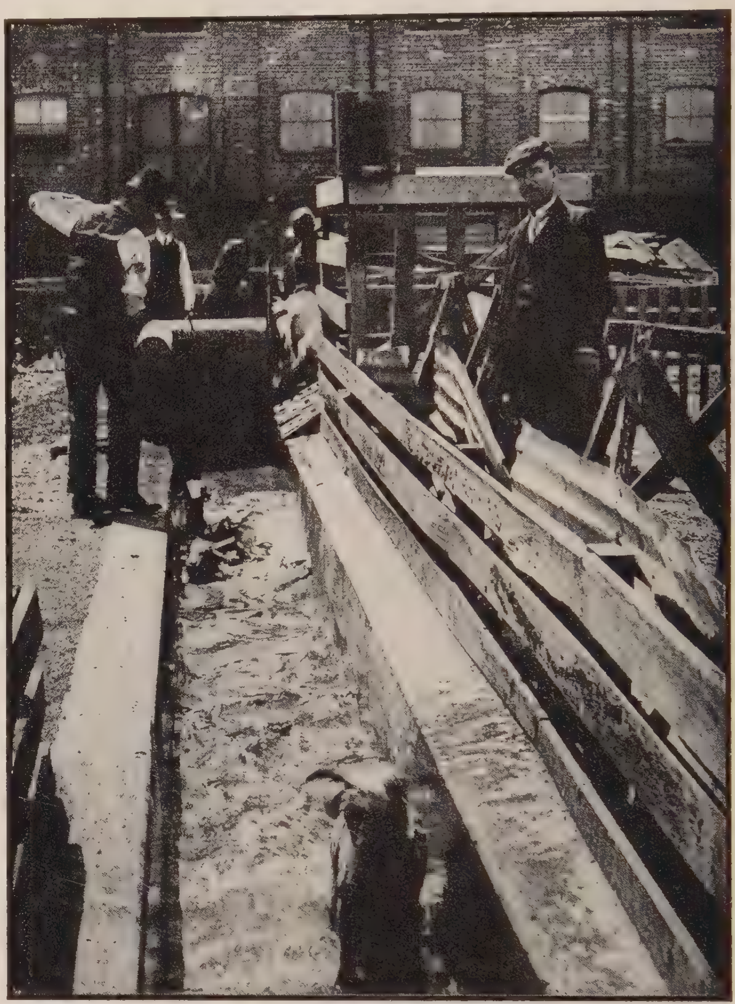
SHEEP-RAISING IN A SUNNY VALLEY AMONG THE ANDES NEAR CUZCO, PERU (FARM BUILDING AT RIGHT) end. Midway stands a shepherd with a staff in hand, and with it he pushes the heads of the sheep under water at least twice as they pass him. This cleanses the heads and eyes of the herd as well as their bodies. If new flocks have been purchased they are kept in a pen by themselves until they are dipped in order to make sure that they are clean and will spread no parasites through the flock.

MAKING UP THE FLOCKS

After the sheep have been dipped they are separated into herds. Each herd must have some "flock-wise" sheep in it to act as leaders for the others. These leaders are often old ewes that have long been in the flocks, or sometimes wethers. A few goats are often of service, as they are able to find food and water without the aid of the herder. Sheep cannot do this. They are the most helpless of creatures. They can find no food or water unless led to it, and if they are separated from the flock they are unable to find their way back. If they had not a strong instinct to keep in a herd and follow their leaders blindly, they would have a sorry life. Therefore, in herding sheep, it is always necessary to have a few wise ones, capable of understanding to some extent the wish of the shepherd. Yet despite the higher intelligence of these leaders, even they will sometimes become panic-stricken and communicate an unreasoning and disastrous impulse to the entire flock. These impulses are called the "flock mind"; frequently it is the cause of herds of sheep doing most unexpected things. Leaders will become frightened and turn back on the flock, at which all the sheep will turn on each other, pile up, and many will be smothered or trampled to death. It is one duty of the shepherd to try and direct the "flock mind" so that no harm will come to the fold.



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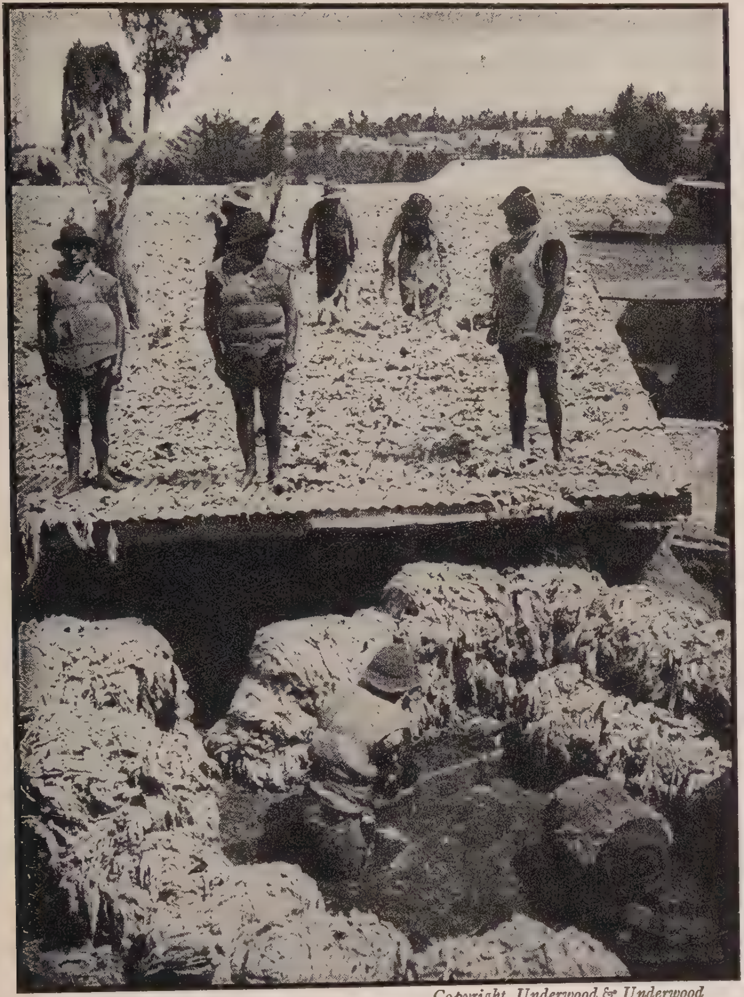
DIPPING SHEEP, NEWMARKET, NEAR MELBOURNE, AUSTRALIA

In addition to the leaders every flock must have markers to aid the shepherd in keeping track of his sheep. All sheep will gradually work themselves into a particular order, and will jealously guard their especial position in the flock.

This is a great help to the shepherd, for it enables him to place a black-faced or crumpled-horned sheep between every hundred; if one of these markers is missing the shepherd calculates that a hundred of his sheep are missing, for sheep seldom divide themselves from the flock unless a whole group wander away.



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WASHING AND DRYING WOOL FROM THE ANDEAN TABLELANDS

MARKING SHEEP

Every ranch owner has a private mark for his sheep that they may easily be identified if they stray or are stolen. Some owners make slits or notches in the ears of their sheep; while others insert a brass clip in the ear of each animal with an anchor or especial device on it.

READY FOR THE RANGE

After the herd has been dipped, counted into flocks, marked, and the bells have been put on, it is ready for the range. Occasionally these ranges are far away, and the herds, shepherds, and dogs must be transported by train; generally, however, the herder sets out at the head of his flock and with the help of his dogs leads them to the mountain plateaus where grass grows in abundance. Sheep can travel about seven miles a day. The eye of the shepherd is constantly on the alert for rich feed and for water holes. It is his aim to get the sheep to luxuriant cool pastures in the hills before the lambs are born in May and June. There are from two to three thousand sheep in these trailing bands, but at lambing time these are divided into smaller groups.

FEEDING ON THE RANGES

It is customary for range sheep to feed on a winter or lower range, and when the snows are melted go up on a higher summer range where it is cooler and where grass is more plenty. Flocks thus raised become very hardy; they climb and run, have pure air and the cool climate necessary to animals protected by thick, warm coats. If, however, undipped sheep pasture on the ranges, they do much damage by infecting the herbage and polluting the water so that other flocks cannot follow without being similarly diseased.

DESTRUCTION DONE THE RANGES

Great havoc, too, is worked on the ranges by careless or unintelligent herders turning too many sheep into the pastures. This is called "over-grazing." Sheep possess two destructive characteristics — their sharp hoofs, which cut the soil and grind it to powder, and their pointed jaws, with such an arrangement of teeth that they can crop the ground very closely. If, therefore, too many sheep are turned into a given area they will not only crop the growth on the surface of the ground, but they will also dig up the roots and leave the spot barren and the soil powdered to dust. Often it is years and years before anything will grow there again.

HOW OUR GOVERNMENT PREVENTS THIS

To prevent this wholesale destruction of the public lands our government issues to "homesteaders" and to stock growers "permittees" allowing a restricted number of sheep or cattle to pasture within a given area. Thus there is plenty of grass for each sheep and the herd is not obliged to crop the roots of the herbage, or destroy the young shoots in the Forest Reservations. "Rangers" in the employ of the government patrol the boundaries of the Reserves to see that no flocks pass in without permittees. At first the government intended to shut out all stock from the National Forest ranges, but as our western states were dependent upon the sheep and cattle industries this plan seemed unfair. So in order to promote the prosperity of the West, not only were grazing privileges granted, but the Department of Agriculture set itself the task of posting notices where herbage was poisonous; of taking an inventory of the water holes; and of decreasing the vast numbers of coyotes which are one of the greatest menaces to sheeping on the ranges. This kindness, which tended to better conditions for the ranchmen, was met at first by scant gratitude. Shortsighted herders, resenting government interference, tried in every way to outwit the rangers, and there was many a feud between herder and ranger. Still the government worked on. It regulated at what seasons areas might be grazed without danger to the growth and made clear that if grass was cropped in the spring before the roots were established it would die; it also showed the shepherds that if herbage was nipped off in the fall before the seeds had ripened they would not scatter and there would be no supply of fodder the next year. Herds were restricted, moreover, from moving through the Forest Reserves at seasons when the young growth of the trees might be injured.

ENMITY BETWEEN SHEEP-MEN AND CATTLE-MEN

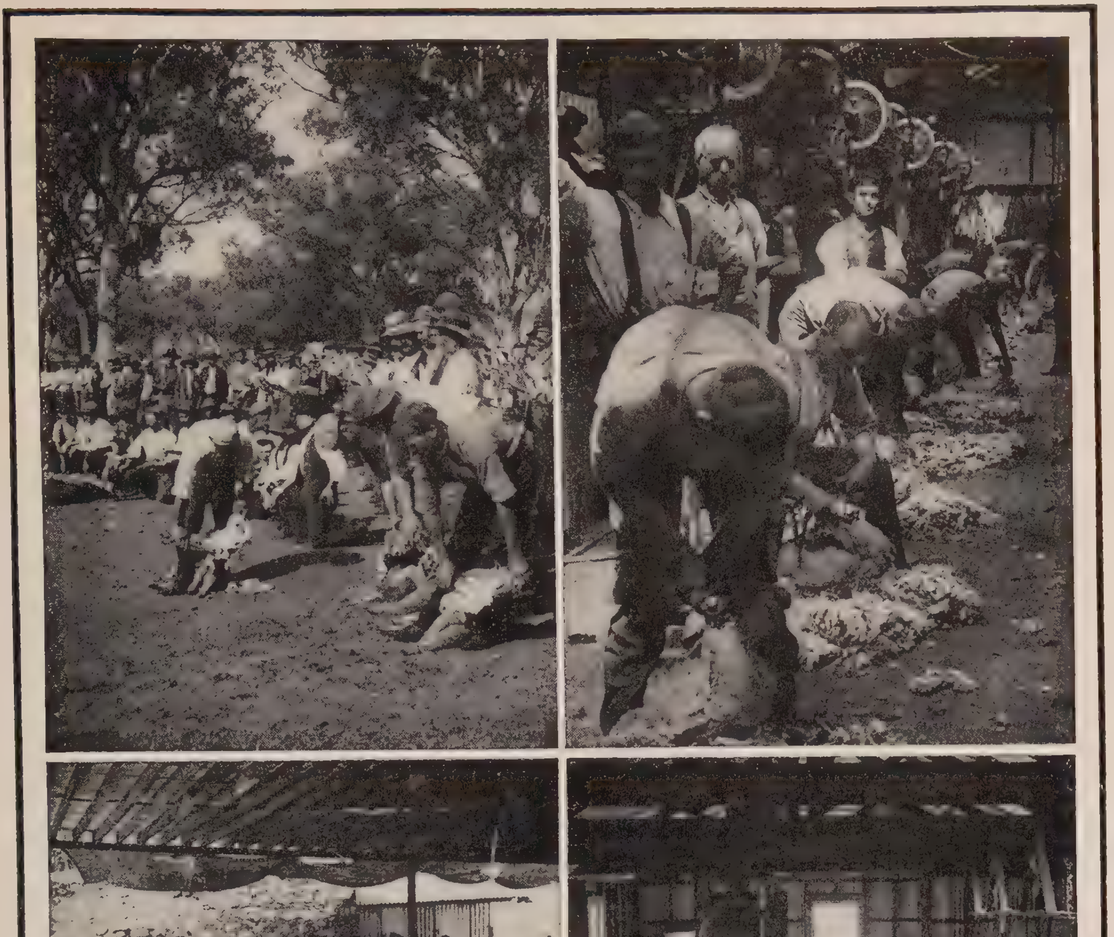
There was yet another evil which the government sought to remedy, and that was the strife between the sheep-men and the cattle-men. Each had his grievance. Since the sheep could crop closer they destroyed the range pastures far more than did the cattle. Then, too, because the sheep had an oily secretion between their toes which kept the hoofs from drying and cracking, a peculiar odor lingered about pastures where sheep had grazed and cattle would not graze there. The sheep-men, on the other hand, declared that owing to the love for standing in marshes and pools cattle polluted the water holes. By allotting a special grazing domain to each party the government has done much to allay this warfare.

ADVANTAGES OF THESE LAWS TO THE GOVERNMENT

At the same time the fees for permittees greatly increase the treasury of our government. The herds enrich the soil, contribute to man's need for food and clothing, and by devouring the light growth on the forest floors decrease the dangers from forest fires. There are 176,000,000 acres of National Forests in which sheep, cattle and horses are grazed. While the number of sheep in the United States varies from year to year, there are normally more than fifty million on farms and ranges. They produce an annual clip of wool of about five hundred million pounds.

LIFE ON THE RANGE

When the flock reaches the range the herder finds a spot where there is plenty of grass and a water hole and here he establishes his camp, allowing his sheep to graze freely during the day and bedding them down around him at night. The herder himself seldom sleeps during



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TOP: SHEARING SHEEP BY THE OLD METHOD, AND HOW A SHEEP IS SHORN IN FIVE MINUTES BY ELECTRICAL MACHINERY, IN AUSTRALIA. BOTTOM: INDIAN WOMEN AND CHILDREN SORTING WOOL AT AREQUIPA, PERU, AND ASSORTING AND PRESSING ROOM IN AUSTRALIAN SHEEP SHEDS the darkness. He is watching his flock. In the daytime he can put the herd in care of the dogs, and can then take his rest or can even journey to a central camp and bring back his provisions if this camp is not too distant. If it is, food is brought him three times a week by a camp-tender who rides hither on horseback accompanied by a pack-horse. A good shepherd will always sleep with "one eye open," however. He must ever be on the alert for the unexpected. His flock may be attacked by coyotes; they may become startled and run. It is a well-known fact that when sheep are frightened they make no outcry, they simply run—often blindly following their leaders over the face of cliffs, or wildly stampeding after them if not headed off. Sometimes, too, when the moon is bright they will start off to graze and will wander far away if the shepherd is not watching. For all these emergencies the herder must be prepared. So long as fodder is abundant the herder will remain at this camp, frequently holding it for ten days or two weeks; then, when the crop of grass is exhausted, he will travel on his way up the range.

LAMBING ON THE RANGE

Range lambs are born in March, April, May, or June—the time differing in different localities. During these busy few weeks the flock is subdivided into smaller groups and more shepherds are sent to aid in caring for the herd. It is at this season that the flock is most at the mercy of coyotes and bobcats, and to protect the young lambs the government has, on many of the ranges, fenced in large areas, transforming them into coyote-proof inclosures. Here portable lambing tents are set up for the ewes. It is an interesting fact that the ewe recognizes her lamb only by the sense of smell; it is possible, if one lamb dies, to fasten upon another the skin of the dead lamb and the ewe will foster it as if it were her own. Young lambs have little body and very long legs. They grow strong quickly and are often able to journey on with the herd in three or four weeks. While they are still young it is well for the shepherd to patrol the flock at night or build fires about it to drive off not only the coyotes but bobcats, bears, and cougars.

PERILS OF RANGE LIFE TO THE SHEPHERD

It would seem at first glance as if this life in the open must be a most peaceful and healthful one for the shepherd. It is, on the contrary, a perilous occupation and fatal to many engaged in it. The isolation on the range is so complete that often months and months pass without the shepherd interchanging a word with one of his own kind. The men are steeped in silence. In time some of them become unable to express themselves at all; it is not an infrequent thing for them to become insane, not alone from the silence and lack of human companionship, but from watching the continual moving of the sheep. Sheep weave in and out, undulating like a mighty sea, until this peculiar motion affects the reason of one forced to watch them constantly. To obviate this danger the state of Wyoming has enacted a law providing that shepherds shall journey in pairs, and that each shepherd must be supplied with a small, compact library. If a herder's gaze is focused upon a book it cannot vacantly follow the movements of the herd, and his mind will be in less danger of becoming unhinged. The

SHEPHERD AND DOG IN MONTANA

herder remains on the range until it becomes cold in the fall, and then he works his way back to the home ranch or to shearing headquarters, which are often situated near the stations from which the wool is to be shipped. Woe be to the herder who has allowed his flock to crop too closely on the way up, for when he returns he will find scant grazing for his sheep.

SHEARING

About the first of April the flocks are sheared, and this is done either by hand or by machinery. There is little difference in the speed or in the expense of these processes. Perhaps power plants clip the wool a bit more evenly. The fleeces are taken off whole, the small parts are turned in, and the fleece is then bound with glazed cord. If fiber cord is used a fleece is often ruined, for the fibers get into the wool and it is impossible to get them out; later, when the wool is dyed, these fibers take a different color and the product cannot be woven. After the fleeces are tied they are packed in huge sacks and are ready for shipping. Many frauds are practiced on the purchasers by dishonest sellers of wool. Since wool is sold by the pound unscrupulous growers will sometimes fill the fleeces with sand in order to run up the weight. If such a trick is discovered and traced to a grower his future crops are boycotted by wool merchants.

HOW WOOL IS BOUGHT

All large wool brokers send their representatives to the wool-growing country when shearing is over, and these buyers bid against each other for the wool. They offer reasonable prices, and if the highest price is not accepted it is agreed among the buyers that none of them will bid again on that particular consignment of wool for at least two weeks. This rule has been made in order that the buyers may not go to the expense of long trips to ranches offering wool for sale only to have their business advances refused.

VARIETIES OF SHEEP

There are many varieties of sheep. The foundation of most of our western herds is the Merino, which is favored because of its tractable nature and its long, fine, and abundant wool. There are Delaine Merinos and Black Tops, both of which are bred from the original Spanish Merino. Then there are French Merinos or Rambouillets. Besides these there are many English breeds of sheep: Leicesters, much raised in Canada and found on some of our western ranches; Cotswolds, which abound in Canada, Utah, and Oregon; Lincolns, the heaviest breed of sheep there is, with very long wool; and the Dorset Horns, which is one of the most ancient of breeds.

The English and Scotch hill regions furnish a supply of Cheviots, Tunis, and Persians. The English Downs foster on their chalky hills a short-haired variety of sheep valuable chiefly for mutton. These are South Downs, Hampshire Downs, Sussex, Oxfords, Shropshire Downs, and Dorset Horns. In addition to the wool raised in the United States much is grown in Australia, England, Canada, South America and Mexico.

COTTON SPINNING IN EGYPT; COTTON PICKERS; COTTON BOLLS; BALES READY FOR SHIPMENT

OUR COTTON CROP

Of the three great kingdoms, animal, vegetable, and mineral, it is interesting to see how each one in its turn ministers to man's three primary needs for food, clothing, and shelter. Man obtains wool by shearing the sheep's close, fine coat; for silk he depends on the careful spinning of the silkworm; but the cotton for his cloth he can grow in his fields even as he raises wheat and corn for food.

Cotton has been grown since very ancient times. For several thousand years the people of India and Egypt and Arabia have been gathering the fleecy fibers of the cotton plant, spinning them into thread and weaving them into cloth. When the earliest explorers came to the New World they found cotton growing in the West Indies. Cortez found the natives of Mexico quite skilled in spinning, weaving and dyeing coarse cloth which they made from cotton.

Today the United States produces nearly half of the world's crop of cotton. A large part of this we manufacture for our own and foreign use; the rest we export in its raw state.

"Cotton," says a leading economist, "has been an outstanding factor in our national history and development; it has exerted a strong influence upon our political, industrial, and commercial life; it has had a most important bearing upon the labor question; it has affected our diplomatic relations with other countries; and it has been for decades the dominant source of our purchasing power abroad."

HOW COTTON GROWS—AND WHERE

If you have never had the good fortune to see a cotton field when the seed pods were bursting, your best picture of raw cotton will probably come from the absorbent cotton which you have seen in stores or in your own home. Cotton is a soft fibrous substance made up of the twisted hairs which clothe or cover the seed pods of the cotton plant. The part which we make into cloth is the soft wrapping of cellulose or plant stuff in which Nature wraps the precious seeds of the plant for protection until they are grown. Within the seed pod, of "cotton boll", as it is called, lies this soft mass made up of hundreds and thousands of tiny fibers which are from one to two or two and one-half inches long. Because they have wound so tightly about the seed, they have a natural twist which persists after they have been put together into one long thread, and which makes one of the useful qualities of spun cotton.

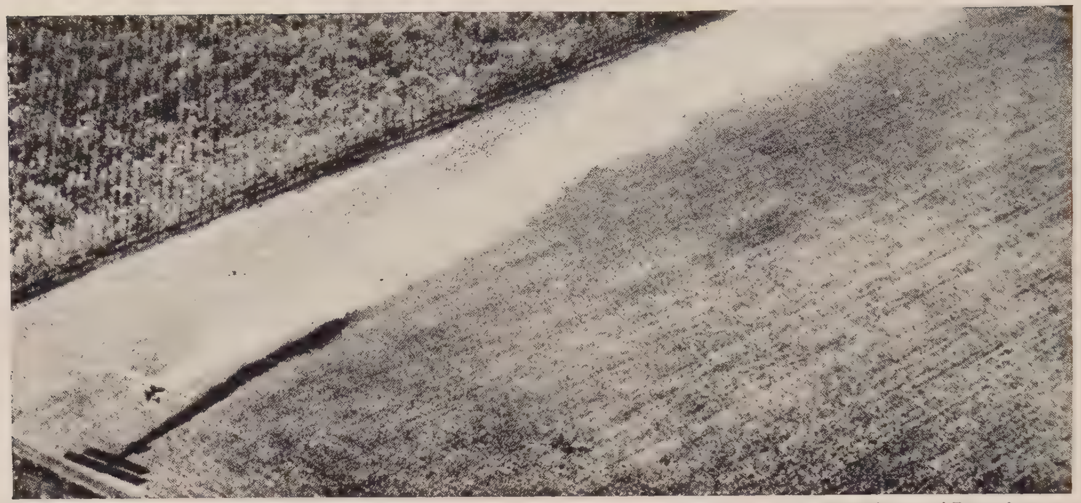
If we were to stretch a "cotton belt" across the United States, as we pictured ourselves placing a "wheat belt" around the globe, the cotton belt would fall farther south. Cotton is a native of the tropics, of South America, Africa, Southern Asia, and the West Indies. The most valuable cotton in the world, noted for its length and silkiness, is called "Sea Island cotton", because it was first grown in islands off South Carolina and Georgia. Cotton was grown in Egypt as early as 325 B. C., and has been used in India for uncounted centuries. The ancient Phoenicians and Hebrews are known to have made cotton clothing, and from them the art was learned by the Greeks and Romans. Early explorers found the native Indians raising cotton in Mexico, Brazil, and Peru. Its range is about forty degrees north and south of the equator, though it grows best within thirty to thirty-five degrees either way. It flourishes in a warm, humid climate with plenty of rainfall and abundant sunshine. The conditions in our own Southern states are very favorable, our cotton belt including all the states from North Carolina through Texas, while the rest of the world's crop is raised chiefly in Egypt, India, South America, Russia, and China.

Cotton in our own country is usually cultivated as an annual, being raised from seed. The plants grow to the height of a low shrub, although there are varieties, found chiefly in Mexico and Brazil, which attain a height of over fifteen feet. The expense of picking has prevented any extensive cultivation of this tree cotton. "Throughout all the cotton belt," writes Fisher, "the seeds of the cotton are planted in the spring. During the growing season the stocky bushes are rich green with maplelike leaves. By midsummer time the fields are gardens of hollyhock-like blossoms, pink and white. Soon these fall, leaving little green seed-bearing bolls, which, when ripe, burst open and show the fluffy white cotton fiber ready for the picking." A field of cotton is a beautiful sight.

Beneath the beauty the planter is watching constantly for the enemies which lie in wait to ruin his crop. The plants must be carefully watched, tended, and cultivated, for they are threatened by diseases which may visit them, by worms which may attack them, and most serious of all by insect enemies, notably the boll weevil. This insect, which came into this country from Mexico in 1892, has worked its way northward and eastward throughout the greater part of our cotton regions. The weevil puncture the cotton boll and lays its eggs in it. The larva which develops from the egg destroys the fibers within the boll. The planters of the South, with the assistance of the United States Department of Agriculture, are fighting this pest with every force modern science can command, but with only moderate success. Millions of bales of cotton, valued at many millions of dollars, are destroyed annually by these insect enemies.

HOW COTTON IS PICKED AND USED

As the cotton ripens in about four months and continues to do so until the first killing frost, the picking season in our country usually begins in August, the cotton being gathered, usually by hand, as fast as the bolls mature.



Photo, Bureau of Entomology

AIRPLANE DUSTING COTTON FIELD FOR BOLL WEEVIL DESTRUCTION

The cotton which matures first and has been least exposed to the weather is considered superior to that picked at the end of the season. Growers tell us that an average picker will gather from two hundred to two hundred and fifty pounds of cotton in a day. Great care must be used in picking to make sure that stems, leaves, and dirt do not find their way into the pickers' bags. The bolls cannot be gathered while they are damp, otherwise the teeth of the gin will cut and spoil the matted fibres instead of separating them from the seeds and stems. The planting, tending, and picking is a great Southern industry, keeping men, women, and children at work.

After it is picked, the cotton fibre must be separated from the seeds to which it clings so tightly. Here the cotton gin, invented by Eli Whitney (of which the story is told earlier in this volume), serves its useful purpose. When the seeds have been separated from it, the mass of cotton is compressed into bales and shipped to the mills, where it is the raw product of one of our great textile industries, as described in a later chapter. While our cotton crop used to be valued only for its cloth fibres, other portions of the plant now contribute valuable by-products. Its seeds are crushed to produce a vegetable oil in quantities valued at over $300,000,000 a year. Short fibres, or "linters," removed from the seeds in this process are widely used in making felt and surgical dressings. The explosive gun-cotton is obtained by soaking cotton in nitric and sulphuric acids and then allowing it to dry. This gun-cotton, dissolved in ether and alcohol, produces the adhesive used by surgeons, which is known as collodion. The stems and leaves provide fodder, and the seed hulls are used as fertilizer. Thus it is seen that there is no part of the plant which man has not converted to some useful purpose.

GRADING AND MARKETING

The price which the planter receives for his cotton depends on its quality or grade, as determined by experienced buyers. Eight standard grades have been fixed by the government, ranging from "low ordinary" as the poorest to "fair" as the highest. The grading is affected mostly by the condition of the cotton. Color plays a part, the choicest cotton being the whitest and cleanest. Lower grades may be dingy in color, may have stains or discolorations, or may contain leaves, stems, hulls, or dirt. The buyer samples the cotton not only for color and cleanness, but "pulls" it to determine the length and strength of its fibers. He also checks its elasticity by squeezing a sample in his hand and watching to see if it will return to its former shape.

The small planter often exchanges his crop for merchandise at a local store. Larger growers place their crops in warehouses for sale to cotton merchants or to representatives of the textile mills. Others, on the other hand, sell to professional buyers who travel throughout the cotton belt, buying crops and concentrating them in warehouses for resale to merchants or mills. Most of the mills, however, do their buying from the great cotton merchants who are the real essentials in the distribution of the crop. These merchants maintain large warehouses, and have branches and representatives through the entire cotton growing region. They purchase from planters and from the small buyers, concentrating their purchases at some central point, and grading and preparing the cotton for delivery to the mills as it is needed.

SILKWORMS AND COCOONS

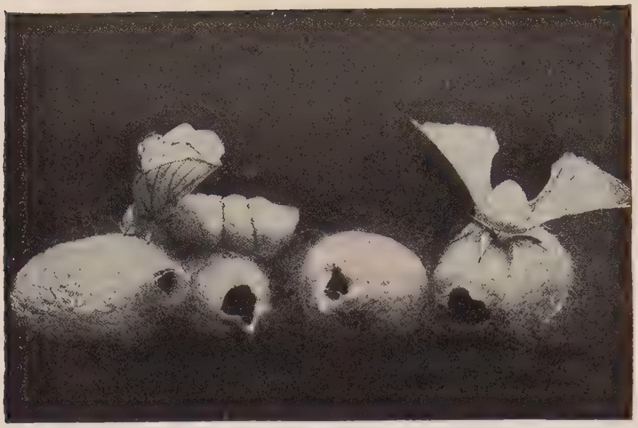
SILK

HOW strange it is that a material as useful and beautiful as silk should have its origin with anything as ugly as the silkworm! Had it not been for the caprice of the Chinese Empress Yuen-fi we might never have known that the tiny, peanut-shaped house spun by the hungry little worm was good for anything at all. It was centuries ago that the old Empress found out the secret of reeling the silk off the cocoon, and spinning it upon a rough sort of loom that she herself concocted. Since then, each year, when the mulberry leaves open, the Chinese make offerings in their temple within the palace grounds at Pekin to Yuen-fi, the Goddess of Silk. Well may they feel grateful to her! It is to her discovery that China owes much of its prosperity. No sooner was the story of the silkworm told in the kingdom than all classes of people set about raising silkworms as an amusement. High and low caught up the novelty. But the Chinese had no notion to tell their secret to other nations — no, indeed! When Alexander the Great invaded Asia with his army and saw there silken garments worn by the Chinese nobles, he carried back to Greece not only some of the new material but some of the raw silk which he succeeded in having woven on crude looms; but where the Chinese got the silk, he could not find out. No sooner did the Romans, who were always alert for anything new and beautiful, see these silks than they procured some of the raw material and learned from Grecian weavers how to make the exquisite, shimmering cloth. Rich Romans of the Christian era went about in silken togas. Emperor Aurelian, who came to the throne in the third century, refused to wear silk himself or let his wife wear it because he considered it far too costly and magnificent; Justinian, on the contrary, had no such scruples, but encouraged the people of his time to make silk until its weaving

SILKWORMS FEEDING ON MULBERRY LEAVES

LARGER SILKWORMS FEEDING ON MULBERRY LEAVES

The pictures on pages 257, 258, 260–262 are reproduced by courtesy of American Silk Journal.



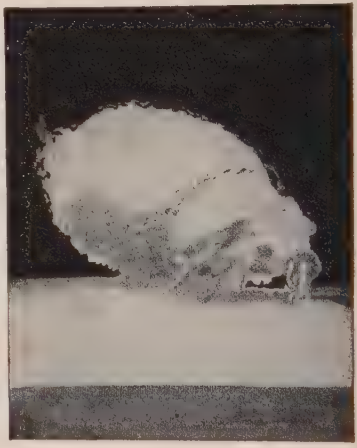
MOTHS BURSTING FROM COCOONS

became one of the industries of the Byzantine empire.

All this time the Greeks and Romans had no idea how the people of China got the raw silk. Where could it come from? Was it a product of plant or tree? Wise men puzzled until their brains were tired and still no answer came to the enigma. Then, the story goes, on one unlucky day a Chinese princess betrayed her country by carrying to India in her headdress some silk-moth eggs and some seeds of the mulberry tree. How delighted the people of India were to learn at last the wonderful secret! They could not keep it to themselves. You know how hard it is to keep a secret. The natives of India must needs whisper the tale to the Persians, and the Persians whispered it to somebody else. Farther and farther spread the story. By the sixth century the Saracens, who overthrew the Greeks, had spread the art of silk-making throughout Europe. Some persons declare that the unfortunate Chinese princess was not responsible for all this and that it was two old monks instead who, dazzled by gold, first carried the silkworm out of China. However that may be, the secret got out and there was nothing the Chinese could do about it. Florence, Milan, Genoa, and Venice were soon manufacturing exquisite silks, and at the close of the fifteenth century France took up the industry, which at first did not thrive there, but which later triumphed over many failures and is now a great source of revenue to the French people.

HOW THE SILKWORM CAME TO AMERICA

It was Flemish weavers fleeing to England in the sixteenth century who carried the industry there, and, since this was about the time of the settling of the Jamestown colony in Virginia, what more natural than that King James I should introduce the culture of silkworms into America? Virginia, however, soon abandoned it for the far more profitable tobacco crop; nor did Louisiana make a success of the venture. Still the king persisted. A royal decree was issued by which in Georgia a settler must plant one hundred mulberry trees on every ten acres of land or forfeit his grant. Still the industry did not prosper. Getting the raw silk off the cocoons was too delicate a task for the great clumsy southern laborers. Besides, the king put a high tax on all weaving machinery. He had no mind to have the colonists manufacture their raw silk themselves. His plan was to take the raw material from them and carry it free of cost to England in order to save the English the expense of buying it from China or Italy. Do you wonder that the American colonists were not especially eager to raise silk under such conditions? After the Revolution a little group of men started raising silkworms in Connecticut, but did not find the scheme profitable. Since that time America has given up attempting silkworm culture. We have no labor so cheap as that in China and Japan, and as raw silk is admitted to our country free of duty we have found that it costs much



MOTH BURSTING FROM COCOON

less to import it from foreign markets than to raise it at home. We do, however, manufacture quantities of silks quite as beautiful as any turned out by the mills of France or Italy.

In Paterson, N. J., are tremendous factories, where some of the finest silks, satins, and ribbons are made. We also specialize in various silk products, some mills making nothing but sewing-silk and twist; others embroidery silks; still others silk fringes. This latter product is made from the short bits which in former times used to be considered worthless and were thrown away. As the silk trade has grown, our factories have steadily improved. We now have in our mills many skilled workmen; we use the most up-to-date type of the wonderful Jacquard loom (see page 267) and we are no longer dependent on foreign designers, since our own art schools send out trained artists whose patterns make a most favorable showing with those of the Old World. These designers have their headquarters in the mills, where they keep in constant touch with the trained chemists who direct the dyeing of material. This is almost a business in itself. The chemist must understand not only what colors to mix to get the shades he desires, but he must also know which dyes fade most easily; which rot the material; what mordant to employ to set the color; and what bath of chemicals will give the silk more weight or body. There is very little pure silk in the market. In China the Mandarin coats, kimonos, and obis made from pure silk are instantly bought up by the Chinese people and seldom reach the outside world. Most other silks, both foreign and American, are loaded with chemicals which give them a stiff rustle termed "scroop" by the manufacturers and cause them to wear out more quickly. Pure silk has none of this crackling sound. Often the cheapest silks will be the stiffest and the "noisiest." It is to be hoped that in time all silk mills will not only give us cheaper and better silk but will do away entirely with "loaded" or false silk.

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SORTING COCOONS, ANTIOCH, SYRIA

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CHILD LABOR IN TURKISH SILK CULTIVATION

THE SILKWORM AND HOW HE LIVES

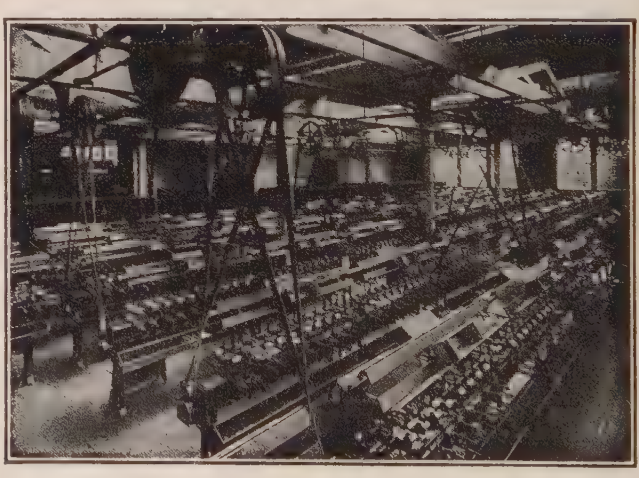
To anyone unaccustomed to raising silkworms the creatures present a most repulsive

JAPANESE GIRLS SEPARATING SILKWORM EGGS FOR HATCHING

appearance; nor is their culture an easy task. They are very delicate, quick to suffer from a change of temperature or from noise, and much annoyed by odors of any sort. Those caring for silkworms are not allowed to use even the most faintly perfumed soaps or colognes. Furthermore the worms will eat but one variety of food, and this must be carefully prepared. If, in addition, the rooms where they are kept are not absolutely clean they often become infected and die. So, you see, many are the trials of the silkworm grower! Only as the result of myriads of disasters does he now meet with his present success.

In the first place the mulberry trees, which grow almost as fast as the worms themselves, must be planted from seed. In three years they mature. Like tea bushes, they must be clipped at the top to keep them low so that their leaves will be well within the reach of women and children whose duty it is to pick them. All fruit must be also nipped off before it starts to mature, that no strength may be taken from the leaves. As the mulberry tree is not one which is in leaf all the year round, the season for raising worms can only last while the leaves last. In consequence the eggs, which are about the size of a pinhead, are kept on sheets of paper and hung in a cold place until the trees begin to bud and there is a prospect of food for the little creatures. All eggs which are to be hatched are first carefully examined with a microscope and those that are diseased are destroyed. The perfect eggs are then placed in incubators to be hatched; if the weather is mild, however, incubators are not necessary. How like a hospital ward is this room in which the young worms are grown! Walls, floors, ceilings, shelves — all are washed and spotless. Since smoke does not harm the worms, the rooms are thoroughly fumigated to banish lurking germs.

In addition there must be good ventilation, for any creature growing as fast as the silkworm needs an abundance of fresh air. The leaves fed to the young worms must be of the tenderest quality, warmed to the temperature of the room, and broken in small pieces. Full-grown worms, on the contrary, must be fed on old tough leaves, as the tender leaves do not agree with them. When the leaves

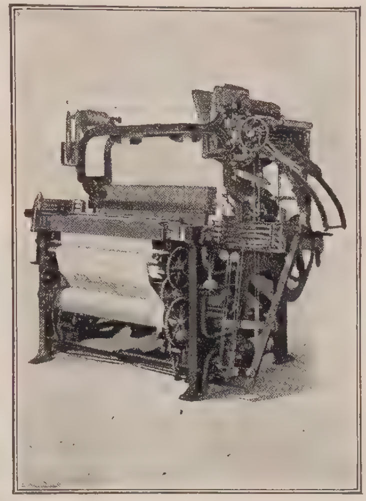


VIEW OF QUILLING DEPARTMENT IN AN AMERICAN MILL are ready they are placed on feeding trays with perforated bottoms in order that all the waste can drop through and be carried away without disturbing the worms.

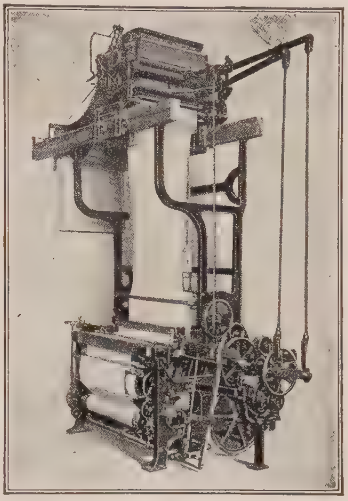
THE LITTLE GLUTTON SILKWORM AND HOW HE OUTGROWS HIS COAT

The tremendous appetite of the silkworm is almost beyond belief. It is said that an ounce of eggs, before maturing, will devour a ton of mulberry leaves. The moment the worm is hatched and reaches the air he swells up many times larger and begins to eat, and day and night — except when he is asleep — he keeps on eating. You might hear, if you were to listen, the crisp cutting of the leaves as he feeds. When about half-grown he is from three to three and one-half inches long, has a head protected by a hard cap, and a pair of large jaws. The glands where the silk is made run the whole length of his body and meet near his mouth in the spinneret, or place where he makes the thread. The silk is like jelly when inside the worm and hardens when it reaches the air. Although there are two glands for making it, it comes from the spinneret a single thread.

OLD-FASHIONED WOODEN SILK HAND LOOM


MODERN LOOM

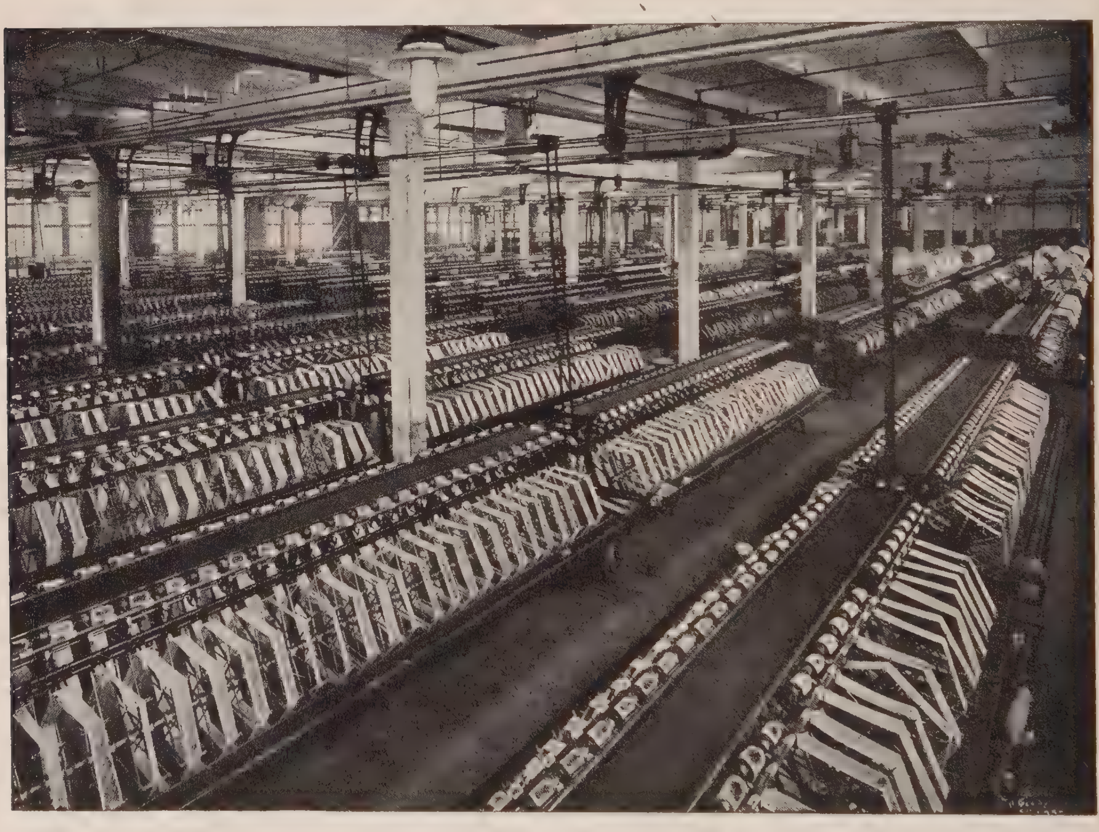
Of course, the more the silkworm eats with his big jaws, the fatter he gets. One skin after another becomes too tight. He sheds the first at the end of five days, hanging himself up as if asleep, until it cracks off and leaves him with a larger one. From this time on he sheds his skin every five or six days. At last, when he has lived about four weeks, he seems to have eaten all he can and he then raises his head and begins to twist and turn uneasily. The men who are taking care of him know what that means. He is looking for a place to build his house. Gently he is lifted to a shelf covered with dried brush and, after selecting a place he likes, he goes promptly to work spinning his cocoon. While he spins there is a soft sound as if rain were falling, and when the attendants listen and hear no more sound they know that the small golden-yellow house which it has taken about three days and nights to make is done.


JACQUARD LOOM

WHAT HAPPENS AFTER THE HOUSE IS MADE

Now if left to himself the worm would sleep inside this house about a month and then, making a hole through one end of it, come out a moth. In doing this he would sever all the silken threads covering his cocoon so that they would be of no further use. If the grower is intending to let the moth come out and lay eggs for other silkworms, he does not interfere, but allows it to mature and come forth; it is then carefully examined with a microscope, and if it is not diseased it is allowed to live. Generally it lives from ten to fifteen days, and in that time lays anywhere from three to seven hundred eggs. It does not fly at all. If on the other hand the grower wishes silk and not eggs, he must prevent the moth from coming out and breaking the thread on the outside of his cocoon. This is accomplished by exposing the cocoon to steam or dry heat so that the moth is quickly killed. The cocoon, together with many others, is afterward tossed into a mixture of soap and water which soaks out the stocky substance blended with the silk. Then the reeler, or thrower, as he is called, who must always be a very skillful person, catches the ends of silk from several cocoons with a brush and, joining them together, winds them off on a reel. This is the most delicate part of silk-making. Some of the cocoons prove to be more cottony than silky, and are thrown out as useless. Others have only short fibers that must be carded and spun like cotton. The silk made from these is called spun silk and is of inferior quality. The best fibers are long, and by joining them a continuous thread is made which is ready for spinning without further trouble; the finest silks are made from this long-fibered thread.

Before weaving, all the silk is scoured or cleaned, and in addition, if desired for silk material of delicate shades or for white silk, it must be bleached. Sometimes the thread is dyed before weaving and these vari-colored threads are then woven into a many-hued pattern against a background of plain color; sometimes, as is more often the case, the pattern is printed on the silk after weaving, just as calico and percale are printed. As it takes from two thousand to twenty-five hundred silkworms to produce a pound of silk, you can see how many creatures probably had a share in making your necktie or your hair ribbon.



WINDING ROOM IN AN AMERICAN PLANT

A SILK FINISH — MERCERIZATION

The luster of silk is so beautiful that attempts have been made for many hundreds of years to obtain this effect with other textiles. John Mercer, a calico printer of England, made the discovery which led to success in this line in the year 1844. One day he was trying to filter a solution of caustic soda through a piece of cotton cloth. It ran through rapidly at first, then more and more slowly until at last it stopped altogether. Investigating for the reason, he found that the cotton fibers swelled until they were almost round under treatment with caustic soda. Working further on the process he discovered that cotton cloth so treated and shrunk was much stronger than in its original form and took on many dyes better. For this process he took out patents in the middle of the nineteenth century, but the strange fact was that he never discovered another effect of treating cotton with this solution, an effect which was to make his name a familiar term in the textile industry. He had allowed the cotton to shrink under the treatment with caustic soda. Fifty years later chemists working with his process discovered that if the cotton was held from shrinking, or stretched before the soda was washed out of it, a silky luster resulted. This is the basis of the modern process of mercerizing cotton to give it a silk finish.

RAYON

In the manufacture of rayon man imitates the spinning process of the silkworm by forcing a semiliquid substance through a tiny opening and letting it harden into a fiber. Cloth made from such fibers was first shown at the International Exhibition in Paris in 1889, but has come to successful commercial use only since about 1918. Cotton linters and wood pulp are the principal raw materials from which rayon is made. They are reduced to the necessary viscous state by treatment with chemicals.

The triumph of chemistry and machinery in imitating the method of the silkworm is known to all purchasers of rayon. In comparison with silk, rayon has certain definite properties. It partly loses its strength when wet, but regains this strength when dried. This ability to gain and lose water and to change its character in the process has been one of its most noticeable characteristics. Of this Mr. Luft says: "The power of absorption of moisture is an advantage of rayon when used for underwear, because it absorbs the perspiration from the body and permits the evaporation of the excess moisture, thus keeping the skin dry and comfortable. . . . It has still another advantage in this respect because natural silk rots from perspiration and turns yellow, while rayon remains white. Real silk is generally weighted with metallic salts . . . Rayon is never weighted; it is a pure cellulose product." Rayon also takes dyes well, which makes it extremely desirable in modern dress where a rainbow of colors replaces the few shades of a half-century ago.

Rayon filaments may be as fine as those of the silkworm or as thick as horsehair or coarse wool. Consequently, all kinds of fabrics, from the sheerest to the coarsest, can be woven of rayon.

CELLOPHANE

Cellophane, the gleaming transparent material so frequently employed as a wrapper for candy bars, cigars, food products, and other articles of merchandise, is also made from the viscous material from which rayon is manufactured. In this case, instead of being driven through small holes, as in the making of rayon, the viscous liquid is forced through a narrow slit and into an acid bath which instantly solidifies it into a thin sheet. A bleaching and purifying process follows to remove all traces of impurities. The final drying leaves a product similar to paper in its uses, but of unusual strength and flexibility. The name "cellophane" is correctly used only in connection with the original product itself, as it is the registered trademark of an American manufacturing company.

Although this unusual material is a fairly recent arrival in the field of manufacture, its uses and possibilities seem almost innumerable. It is as crystal clear as plate glass. Products wrapped in it are visible for careful inspection, yet are safeguarded against soiling and possible damage from handling. Some kinds of cellophane are moisture-proofed to provide added protection. Other varieties are made in brilliant colors to add attractiveness. Starting from the same source as artificial silk, cellophane really becomes a valuable new kind of wrapping paper.

FROM FIBER TO CLOTH

WE have followed the cotton from its Southern fields, the wool from the sheep ranches of the West, the silk from the mulberry trees of the Orient, up to the doors of our modern mills. Each comes to the mill as a raw product, sometimes as beautiful as the skeins of lustrous silk which the Syrian girls in our picture have spun, but more often as matted and uninviting as the bales of cotton and wool. It enters the mill doors and is swept away from our sight into a world of machinery; it comes out transformed into great bolts of beautiful smooth-woven yards of fabric suitable for wearing apparel. The transformation is as complete as in the conjurer's tricks of our youth, and to the uninitiated almost as mysterious. In at one door as a fiber, out at the other as cloth — that is the magic which is worked in our textile factories.

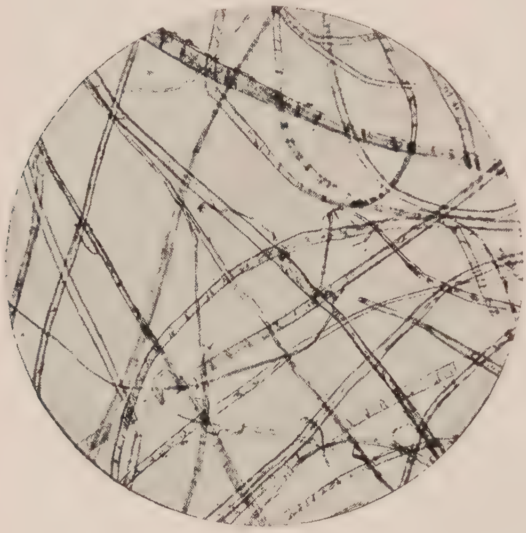


Photo by Gravelle

FIBERS OF FLAX
(Greatly Magnified)

ONE FIFTH OF THE WORLD AT WORK

In her book on "Textiles" Mrs. Woolman tells us that one fifth of the working world is said to be occupied at the present time with weaving, its allied arts, and the distribution of the products of the industry. It is probable that only the food industry surpasses it in the number of its workers. It was reckoned recently that thirty out of every twenty thousand persons in the United States were engaged in the single branch of the business which has to do with the production of wool fabrics. In the cotton industry alone there are probably forty million spindles at work at this instant in this country turning cotton fiber into thread.

THE SIMPLE PROCESSES

The processes of spinning and weaving are among the oldest of human arts. The story of the invention of machinery to do this spinning has been told earlier in this volume. Spinning is the drawing out or twisting of a series of fibers into a long yarn, rope, or cord. Before it can be done the fibers must be opened or disentangled from the mass in which they come, and smoothed for use. This process is called "carding" and is done with an instrument not unlike a comb. "Combing," as the word is used in the textile sense, differs from carding in this way: in the latter process all the fibers are collected together, while in the former only the longer fibers are collected and the short ones are combed away. All raw textile materials must be carded; some are combed and some are not, according to the kind of fiber and the purpose for which it is to be used. In the color plate facing page 177 we see the simplest processes of spinning on a stick or spindle and weaving on a loom.

Weaving is the interlacing of two lines of thread in such a way that they cross each other at right angles. (Look at the pictures of rug and bag weaving in Volume VI, pages 351 and 352, to see the simplest possible weaving, and at the picture of table-mat weaving on page 354.) In such a pattern the threads that run the long way of the cloth are called the "warp"; those that cross them at right angles are called the "woof." To make short fibers into a smooth, long thread they must be spun; to make thread into cloth the threads must be crossed on each other or woven. Such are the simple and necessary processes on which this whole set of textile industries is built.

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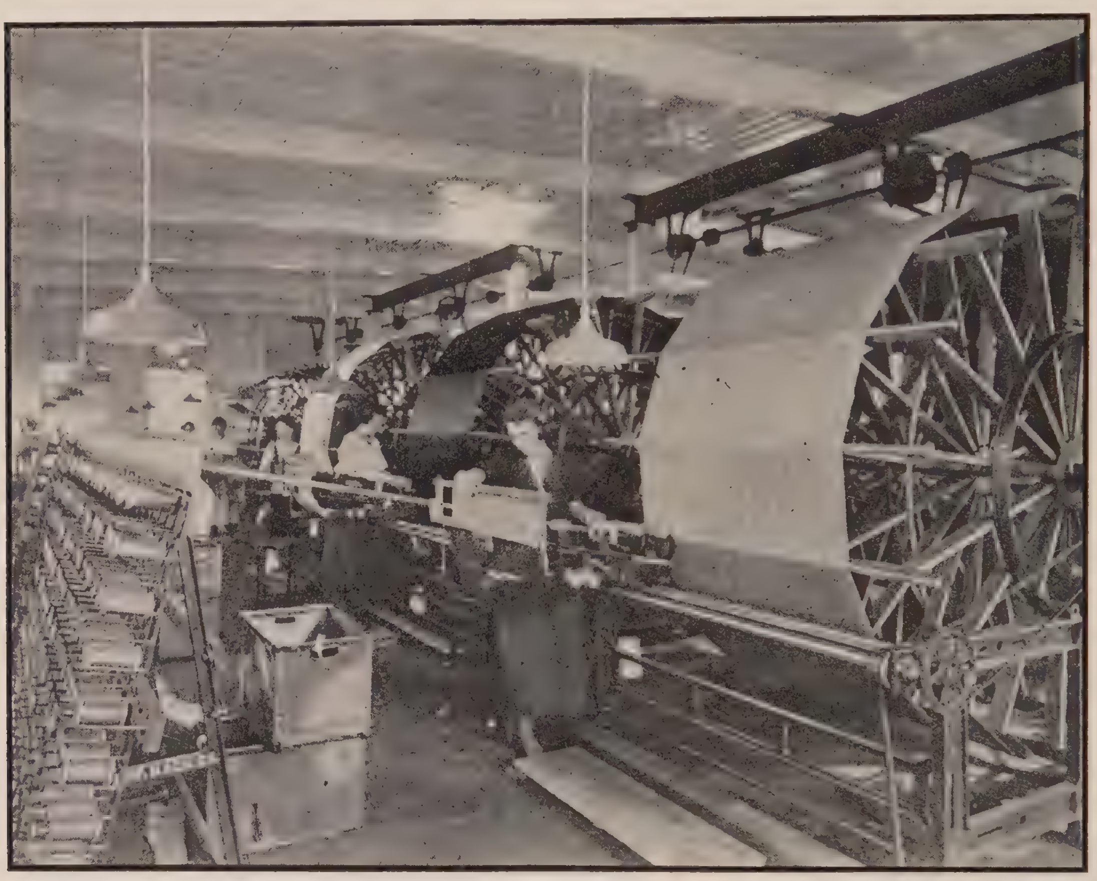
IN A SYRIAN SILK PLANT — EXAMINING AND WEIGHING RAW SILK

TEXTILE MACHINERY

Power spinning and power weaving as practiced by modern machinery repeat the simple hand processes in vastly more intricate ways. It would be impossible to describe these machine methods here; yet we can see in our photographs that the same things are being done by these machines that were formerly done by hand. In the accompanying picture are shown young girls in the warping room of a silk mill, tending machines that tower above their heads. Yet we can see that even on this big scale the warping process is the same as that practiced by the child who lays his threads in parallel lines on a toy loom. The thread is on the dozens of spools at the left of the picture. How many threads shall the operator of the machine lay to each inch-width of cloth? The warp of a light silk may have one hundred to the inch; that of a heavy, four hundred or more. The girl tends and guides these threads as they come from the spools to be laid in parallel lines on the great wheel-shaped machine behind her. The drum above her head may be as large as eight feet in circumference. On this machine we get the first hint of the cloth that is to be. Next it must be woven with a plain weave, or in the case of a fancy cloth with a special and elaborate weave.



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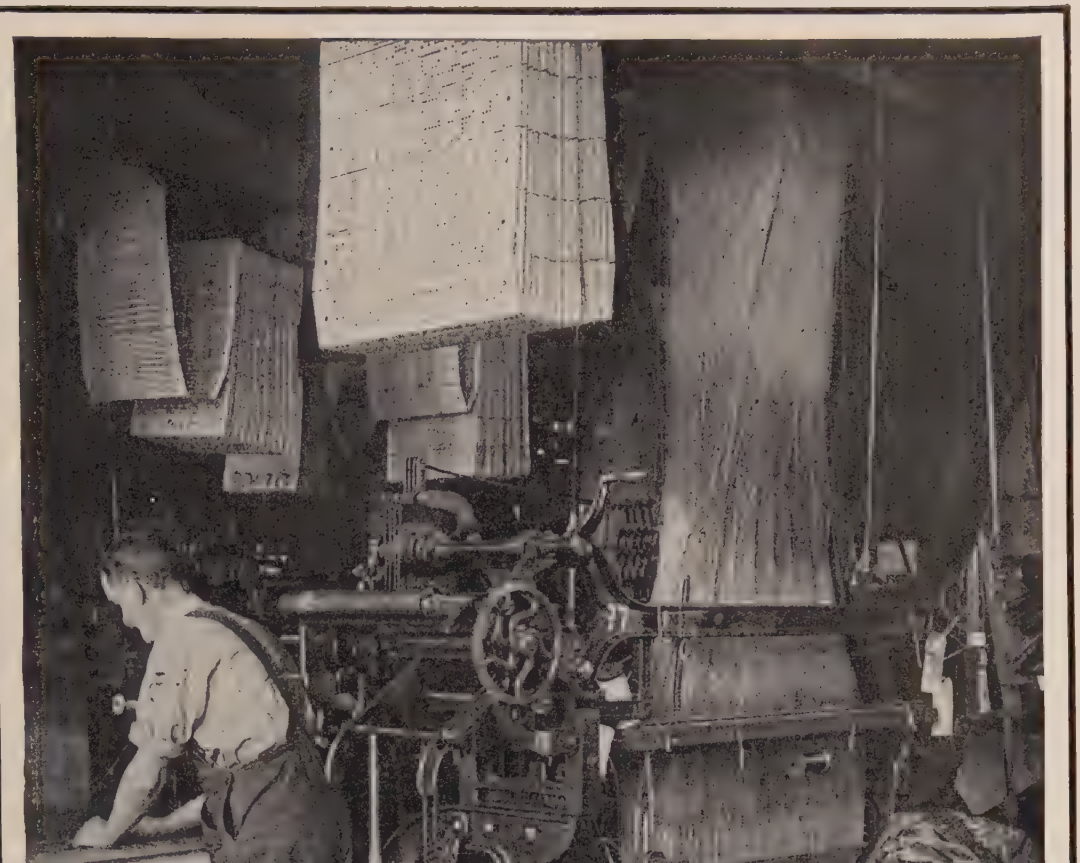
IN THE WARPING ROOM OF A SILK MILL

THE VARIED OUTPUT

Beyond the simple weaving there is the elaborate pattern weaving done on such marvelous machines as the Jacquard loom (here shown), in which we see the perforated sheets of the pattern held high above the man's head. By a mechanism that is almost uncanny in its capability the threads will be guided into their proper position and relation. Another phase of the industry is the dyeing of all these materials, either in the thread before it is woven or in the cloth at its various stages, and the printing of patterns in color. Any one who goes into a department store and looks at the yard goods as they range from the simplest cottons to the most elaborate figured velvets, carpets, and upholstery or drapery goods, and thinks that all this array



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THE MARVELOUS JACQUARD LOOM

Used for fancy pattern weaving. Note the pattern sheets unfolding above the machine of brilliantly colored and elaborately woven material came first from the raw products and then from the spool-thread into which they were spun, will come out with a new sense of the contribution which textile machinery makes to our modern world. Nor do the textile industries limit their output to the materials for the home which can be seen in such a store. The fisherman pulls up a woven sail to catch the wind; the electrician calls for woven stuff to insulate his wires; the dentist and the surgeon call for the finest of silk floss; the machinist, for the strongest of conveyor belts for his machines; the automobile manufacturer, for the backing for his rubber tires. It is an endless and ever-varying demand that is made on the textile industries for their products.

COTTON

Each raw material has its own characteristics, which make the treatment of it during the processes of manufacture somewhat different from those of any other. It would be impossible in so simple and brief a story as this to cover the ground of any single textile or any complete process. Yet it is interesting to note at random some of the specialties of each kind of fiber and the results in those finished products with which we are familiar.

We have spoken of the natural twist in the cotton fiber. This helps in the spinning of it, and also makes for a strong thread. The stronger the twist, the greater the elasticity of the fiber. Cotton fiber is stronger than wool fiber. It is, however, soft, and the length of the staple (that is, of the average fiber) is comparatively short. For this reason cotton depends much on finishing processes. Early in the manufacture of cotton cloth it is necessary to apply sizing to the yarn so that it may stand the strain of the weaving. The size is a starchy or glutinous material, like glue or flour, applied in liquid form to the thread, and acts like a glaze. It is often difficult for the purchaser to estimate how heavy a piece of cotton goods really is because there is so much extra sizing which will disappear after a few washings. Besides this simple sizing, cotton goods are treated with many dressings and finishings to produce different effects. The housewife practices one simple method of dressing when she starches cotton garments. A soft finish is obtained by treating with oils; a gloss, as in percales, by applying a mucilage mixture; stiffness, as in linings or organdies, by another formula of mucilage and gums; firmness and weight, as in cretonnes and canvases, by applying a clay preparation.

The fact that cotton takes on a finish so well makes it the basis for many imitations of other cloths. It can be made to acquire a wool finish, as in flannel, or a silk finish, as in mercerized cotton. To mercerize cotton it is treated with an alkali (caustic soda) in a cool temperature, then put under tension, and lastly rinsed. This causes the cotton to become more lustrous, a little stronger and better in color when dyed. This process gives a finish which does not vanish when the fabric is laundered. By heavy pressing or "calendering" a mercerized finish is produced which does not remain after washing. Real mercerization is expensive and adds to the value of the cotton, so that it is well to wash a sample of mercerized goods before buying, in order to find out whether the finish is permanent or not, before paying the extra price for the material. Cotton also combines well as a basis with other fibers, so that we have to-day many cotton and wool, or cotton and silk, or cotton and linen preparations.

WORSTEDS AND WOOLENS

When wool arrives at the factory, it is in fleeces, each fleece having several kinds of fibers — long and short, coarse and fine — according to the part of the sheep's body where it grew. These have to be carefully sorted into piles. The wool must also be thoroughly washed to rid it of a fatty secretion from the skin of the sheep. Woolen goods are of two kinds, — worsted fabrics, which are made of yarns in which all the fibers lie parallel; and woolens, which are made from yarns in which the fibers cross or are mixed. In general, worsteds are therefore likely to be made from the long staple wools, while woolens with their crossed or mixed fibers can be made equally well from the short staple wools. In different breeds of sheep the length of fiber varies from two to twenty inches.

This animal hair requires different and in many ways more particular care at every stage in the process of manufacture than some of the vegetable products. It is more subject to variations in temperature; the sorting is particular work; the dyeing, the sizing, and the final dressing are all critical chemical processes. All woolen goods depend much on color for their beauty. The dyeing may be done early in the process, when it is said, in our familiar phrase, that it is "dyed in the wool," or in the thread after it has been spun, or in the piece after it is woven.

SILK

Silk is outstanding among natural fibers because of its strength, its light weight, its fineness of weave, the smoothness which makes it shed dust, and its luster. Pure silk is so beautiful that it needs no dressing, only the bringing out of its own natural sheen. The cheaper silks take up a good deal of dressing, which, with the skill of the modern chemist, gives almost the effect of the pure original. Many of the properties of natural silk are now imitated by artificial fibers such as rayon and nylon. As a result our consumption of real silk has decreased considerably.

LINEN

No story of textiles would be complete without a mention of linen, a vegetable product corresponding to cotton, made from the fiber contained in the stalk of the flax plant. No matter what the combinations of other goods and the finish put on other materials, linen holds its own on account of the properties of its fiber, which it carries on into the finished cloth. Linen is naturally smooth; the fibers are very strong, and therefore wear well; water evaporates from it quickly, which makes it desirable for towels and handkerchiefs; it cleanses well and stays white, which makes it ideal for tablecloths and napkins; it has a good luster of its own. It is unfortunate that so much land once under cultivation for flax has been turned to other uses. It is to be hoped that flax culture will be resumed in our own and other lands, for linen is a cloth for which there is no adequate substitute.

"RE-PROCESSED" AND "RE-USED" WOOL

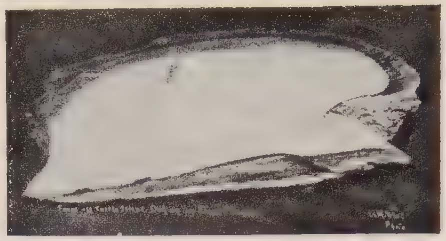
The world's wool supply is not sufficient to supply new wool for all the woolen goods required. Consequently there is the practice of reclaiming old wool and using it again. This recovered wool may be very good or may be very poor. The Wool Products Labeling Act of 1941 requires that all wool products, except carpets, rugs, mats and upholstery fabrics, which are sold in interstate commerce must bear labels which reveal the percentages they contain of "Wool," "Re-processed Wool," "Re-used Wool" and any other fibers which amount to five per cent or more of the total fiber weight.

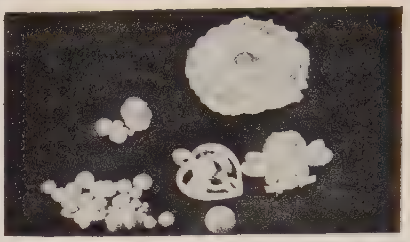
"Wool" means new wool which has never previously been made up into a fabric. "Re-processed wool" means wool which has been made into fabric and then reclaimed but which has never been used by the consumer. "Re-used wool" means wool which has been made into fabric and used and then reclaimed for further use.

There are many different breeds of sheep and the wool from each breed will differ from others. From different parts of the fleece of the same sheep we get different grades of wool. The price varies on differing grades of wool. A high grade or "re-processed" or "re-used" wool actually may cost more than a poor grade of new wool and, for its particular purpose, may be preferred over the poorer new wool. "Re-used" wool is entirely sanitary. In the operation of reclaiming it the wool is thoroughly sterilized.

KNITTING

One more process of manufacture should be added to our textile list. The old hand process of knitting, with which we are all familiar, has been adapted to machinery, and a great variety of knit goods, from sweaters to underwear, hosiery, and yard materials, is found on the market. Knitting, as distinguished from weaving, is the interlacing of yarn or thread, not by laying them at right angles to each other but by running the thread through a series of loops, each catching into the stitch before it. This, too, can be done effectively by machine methods, and there are many knitting mills in various parts of our country.





Pearling is a great adventure and a great industry. The pearl is the only jewel which the sea produces. It is of great price and there is danger in seeking it. The shell, the mother-of-pearl, is what makes pearling pay. Pearls are found in only about five per cent of the shells recovered on any pearling ground. Pearlshells and pearls are found over vast tracts of tropic seas. In western Australia the industry flourishes all up the northwest coast. The diving dress is used now entirely. In early days naked aborigines did the diving: now it is a science of complicated mechanism and appliances.

SEEKING GEMS MADE BY IRRITATED OYSTERS

Top: Work of an irritated oyster bent on covering the organism annoying it. Pearls and shell ornaments. Center: Opening the oysters to find pearls. Bottom: Unloading shell from a typical pearl "lugger" or boat. A pearling fleet, high and dry at low tide.

NATIVES DRILLING PEARLS

For use in necklaces and pendants pearls are bored with a steel drill and threaded with silk, an easy operation on account of their softness. These are called "seed pearls."

GEMS

THE custom of wearing gems originated centuries ago among the Egyptians, Greeks, and Romans. These people, however, did not wear such stones because of their beauty or their value, but because they believed that in them lay some charm against misfortune. Certain stones were considered lucky, others unlucky; some brought health and prosperity to the wearer, some were supposed to turn dull and lifeless in the presence of an enemy. The diamond was believed to ward off lightning; the opal to be unlucky; the amethyst to drive away evil spirits. Not all these superstitions have been routed even now, for there are still so many persons who hesitate to wear the opal that not nearly so many of these beautiful stones are sold as there probably would be if this stigma did not attach to them. Many are the interesting tales of fact and fiction based upon beliefs as to the miraculous powers of these gems. It is surprising how they persist.

To those of us who have not studied the qualities of the various jewels, it seems as if it must be very hard to detect real gems from imitations, and we have perhaps wondered how it is that those who handle them are so sure of their value. Why is not any flashing white stone a diamond? What is it that makes one sparkling brilliant worth a fortune, and another worth nothing at all?

HOW GEMS ARE TESTED

The person whose eye has been trained to the observation of jewels will almost instantly detect the true from the false; but if he cannot do this by sight alone there are several infallible tests to help him. It is not the color that decides him, for sapphires are often yellow or pink instead of blue, and there are green garnets and yellow diamonds. No, the expert cannot judge the stone by the color. He judges it by its formation. All gems are crystals which conform to certain laws of structure. The study of crystallography tells just how each of these crystals is made up. To this knowledge the expert adds his knowledge of minerals — which stones are hard, and which soft. The diamond is the hardest stone we have; next to it comes the sapphire, then the ruby, and so on down the scale of twenty-one stones to the opal and turquoise, which are but three-fifths as hard. The test for hardness is made by scratching the stone to be tested with every other stone until one is found which will neither scratch nor be scratched by the other. These two stones, it will then be readily seen, must be alike in hardness. In making this test great care must be taken not to scratch the facets, or faces, of the stone; generally a trained lapidary (expert in gems) will recognize the quality by the merest touch on the edge of the gem. Another test used is to weigh the jewel against an equal amount of water; and still another test may be made by chemical solutions which act in specific ways upon certain gems. But if a gem answers satisfactorily to all these tests there is still the chance of its value being lessened by flaws — that is, by having some foreign substance or defect embedded in it. In cutting gems the lapidary always tries to cut off these flaws, or to cut the stone in such a way that they will mar the beauty of the jewel as little as possible.

HOW GEMS ARE CUT

It was not until a comparatively recent date that people found out how to cut gems in such a way that it would bring out the greatest beauty in them. The ancients had no knowledge of crystals or of minerals, and therefore they either wore their jewels uncut, or they cut them in a crude fashion quite regardless of their real formation. Sometime in the fifteenth century, however, a gem-cutter from Bruges discovered that a diamond could be made far more brilliant by so arranging its facets that the light would reflect through them and split into prismatic rays. Immediately the finest gems were sent to Bruges for cutting, and the place became the center of the industry; but after the death of Van Berquen, this famous gem-cutter, his workmen scattered to Amsterdam, Antwerp, and Paris, and these cities in turn became well known for their work. Now there are gem-cutting establishments in England and the United States as well. In all these places, however, the same methods are followed as were in use so many years ago.

There are three operations necessary in cutting a diamond — "bruting," "polishing," and "cleaving." In bruting a diamond another diamond is used. Each stone is first cemented into a holder and then the two are rubbed together until the constant friction changes the shape of the one to be cut to the form desired. During this process a fine diamond powder, much like that from a slate pencil, is ground off and falls into a sieve beneath; this powder is later used to polish the stone. The stone, having now been shaped, is ready to be polished, and it is therefore taken from the holder into which it was cemented for bruting and is soldered into a cone of tin and lead called a "dop." The small flat facets are then polished off by a revolving wheel or "skeif." If the stone becomes so hot from the friction that the dop in which it is held is in danger of being melted the whole thing is plunged now and then into cold water.

The three forms for cutting gems are known as the "brilliant," the "rose," and the "briolette." Most valuable stones are cut in the brilliant, an octagonal surface surrounded by thirty-two facets reaching from the edge of the stone towards the center. At the back there are twenty-four facets which mount upward in a pyramid form; the apex of this pyramid, however, is smoothed off parallel to the front face, or table, of the stone. Rose cutting is used only for thin or small stones, and the gem is left perfectly flat on the back and cut in triangular facets of equal size on the front. The briolette cutting is seen on most pendants and jewels of pear-shaped form, the surface of such gems

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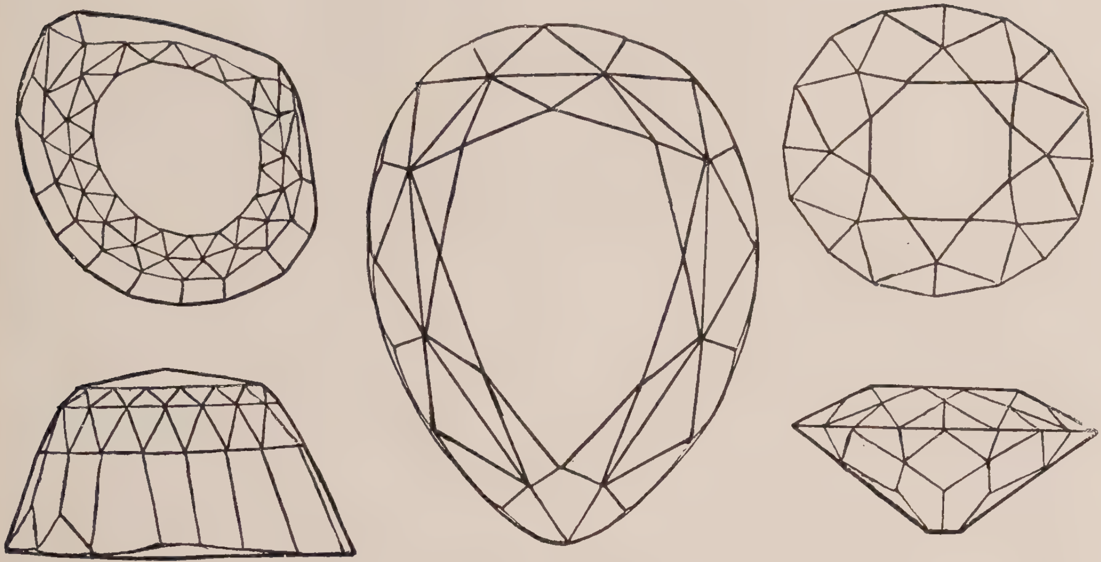
SORTING THE ROUGH DIAMONDS, DE BEERS MINES, KIMBERLEY, SOUTH AFRICA



THE SHAPE AND FACETS OF THREE FAMOUS DIAMONDS

Left: Top and side view of Orloff diamond. Center: The larger of the two sections of the Cullinan diamond. Right: Top and side view of the Koh-i-noor. [Illustrations on pages 271, 273, and 274 from "Gem Stones," James Pott & Co., N. Y.]

being cut in a great number of tiny triangular faces.

When gems are very irregular in shape or are marred by serious imperfections, large sections of them must sometimes be taken off, and this is done by splitting the stone in the direction of its natural cleavage. You all know how wood will split with the grain. The same law holds good with crystals. They have a natural tendency to break off in the line of their planes, or faces. Here again the workman must have a knowledge of crystallography.

Working at diamonds requires much strength, while the work on softer stones must be more delicate. Most transparent stones are cut in brilliants, but the emerald is an exception to this law, being cut square or oblong. Stones such as the opal and moonstone are polished off with a curved surface.

DIAMOND MINING IN SOUTH AFRICA

At the present time most of our diamonds come from the mines of South Africa. Here there are diamond-bearing veins of earth which are worked by sinking shafts just as we do for coal. After this earth is taken from the mine it is sent to a washing-plant where the heavier part which contains the diamonds is separated and sent on through various machines until everything is drained off except the diamond-bearing gravel; from this the gems can be picked out by hand or removed by machinery. Many diamonds are found in the sand of rivers coming from diamond-bearing localities, and often men who wash this soil by hand find in it valuable stones.

SOME FAMOUS DIAMONDS

Some of the largest and most famous diamonds of the world are the Star of Africa, 516 carats; the Great Mogul, 279 carats; the Excelsior, 239 carats; the Orloff, 193 carats; the Koh-i-noor, 186 carats; the Star of the South, 125 carats, and the giant Cullinan, which has been cleaved into two parts, one weighing 516 carats, the other 309 carats, besides a number of smaller stones.

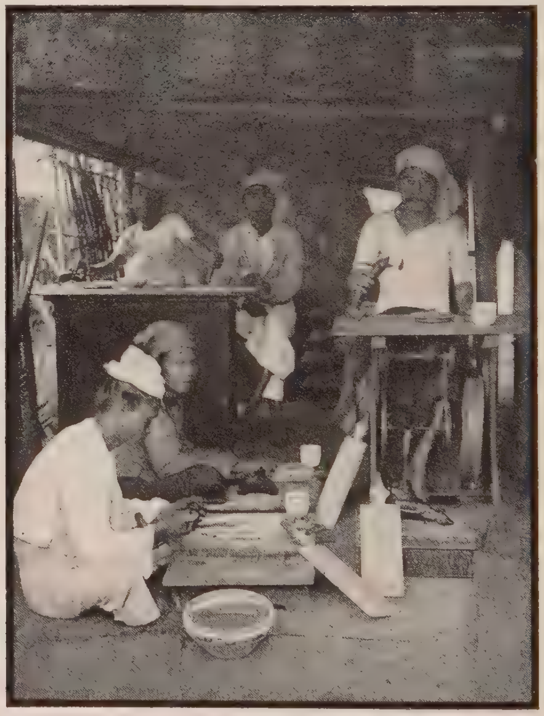
The Koh-i-noor, like the wonderful "Black Prince's Ruby," the Star of Africa, and the Cullinan, are among the crown jewels of Great Britain. The world's most splendid collection of crown jewels formerly belonged to the royal family of Russia, but has been broken up by the present government.

STONES OF OTHER KINDS

The ruby, sapphire, oriental emerald, oriental topaz, and oriental amethyst all belong to the same general family, but their difference in color makes a vast difference in their value. The rubies from Burma, Siam, and Ceylon are the finest, although the Burmese rubies far surpass the others in color. The sapphire is the chief gem of value to be found in the United States; some stones of most beautiful cornflower blue, coming from Montana, rank as the finest in the world. Emeralds come from Africa, Asia, Australia, and North America, but the greatest number are found in South America — Colombia and Peru. There are also numerous semi-precious stones, such as lapis lazuli, jade, and agate, found in quantities in Switzerland, Russia, China, and Japan, while tourmalines and other kinds have the United States as their source. (For further information on precious stones, see the section on "Precious Stones and Gems" in Volume I, pages 191–194.)

At present, artificial or "synthetic" gems are manufactured in laboratories and conform to almost every test of the genuine stone. The art of making small crystals was discovered by Gaudin in 1837 and was further perfected in 1877 by two Frenchmen who succeeded in making crystals large enough to cut. Since then, many manufactured gems, some of them wonderfully beautiful, have been made; among them pearls which can be told from real pearls only by an expert. The Japanese have developed an interesting industry through the cultivation of actual pearls. These they produce by introducing an irritating substance within the shells of oysters, which promptly proceed to build up a natural pearl as a protection against the material which annoys them. Although rubies and sapphires are artificially made in commercial sizes and quantities, diamonds and emeralds are still laboratory products. Various semi-precious gems can also be made commercially but not profitably as the natural stones themselves are not of sufficient value.

A NATIVE RUBY MARKET AT MOGOK, UPPER BURMA, A CITY BUILT AROUND THE RICHEST RUBY MINES IN THE WORLD



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RUBY CUTTING IN A NATIVE SHOP, WITH RUDE TOOLS, BUT PRODUCING REMARKABLE GEMS, IN THE FAMOUS MINES, MOGOK, BURMA

American Tobacco Company

A SOUTHERN TOBACCO FIELD

TOBACCO

No one knows when the first pipe of tobacco was smoked. It is certain that pipe smoking originated in America and was a widespread habit long before the coming of Christopher Columbus. It remained for Francisco Fernandes, returning to Spain from an exploration of Mexico in 1558, to introduce the tobacco plant to Europe. It was at first accepted as a healing herb of marvelous power. Not until Ralph Lane, the first governor of Virginia, and Sir Francis Drake brought an Indian pipe to Sir Walter Raleigh in 1586 did smoking find a foothold in the European countries.

To-day, tobacco is an important article of commerce. Its sturdy plants may be seen growing in almost any locality, and it is estimated that the world production reaches the enormous total of four billion pounds each year. Because tobacco requires peculiar conditions of soil and climate, the finer grades can only be cultivated in certain favored countries. Cuba, for instance, grows the kind of tobacco most favored by cigar smokers, yet its crop is comparatively small. The United States grows over 1,300,000,000 pounds annually, mostly in North Carolina, Kentucky, Virginia, Tennessee, South Carolina, Pennsylvania, Georgia, Ohio, Wisconsin, Connecticut, and Maryland. Second in quantity grown is the British empire, producing over 1,100,000,000 pounds each year in Canada, India, Borneo, and the British sections of Africa. The crops of Japan, China, Russia, the East Indies, Turkey, and Brazil also contribute heavily to the world's total.

GROWING TOBACCO

Most of the world's tobacco is grown from seeds of the Virginia variety, an American plant with a single large stem sometimes reaching six feet in height, and coarse leaves which are often two feet long. The young tobacco plants, raised from seeds sown in beds, are transplanted into thoroughly fertilized fields and cultivated with extreme care during the growing season. Only eight to twenty leaves are allowed to remain on each stalk, and flowering buds are carefully clipped off. In some sections, the plants are protected by great canopies of thin cloth erected over the fields to provide shade.

In about three months the plants are ready for harvesting. While in some kinds of tobacco only the leaves are picked, it is most usual to take the entire plant, cutting the stalks close to the ground where they are allowed to remain until the leaves are slightly wilted. At this period the plants are hung by the stems on long sticks and carried to the curing barns.

CURING, FERMENTING, AND AGEING

In these large buildings they remain for three or four weeks, undergoing the "curing" process, in which heat and moisture are applied to make the tobacco mellow and to soften the leaves so that they will not break when handled. Then follows a period of "sweating" or fermentation, during which the tobacco is piled on the ground and covered with blankets. In this process the last trace of rankness is removed and the color takes its final step in the change from green to the rich, dark brown with which we are all familiar.

Nothing now remains but an "ageing" process, during which the tobacco is packed tightly in bales or great barrels and stored in warehouses. Yet it is a long while before the tobacco will go to the smoker, as it is often aged for three or four years before it is considered fit for use.

Pipe tobacco is the simplest form in which the manufactured product is sold. The leaves are stripped from their stalks, moistened in great steam-filled cylinders, and pressed into cakes. Machine-operated knives cut these cakes into shreds, and these sometimes undergo a final roasting process designed to remove some of the moisture and improve the flavor before packing into tins or jars.

THE MAKING OF CIGARS

At first, cigars were merely a handful of tobacco leaves, rolled between the palms of the hands to prepare them for smoking. Now the making of cigars is a great industry, over six billion of them having been made in the United States alone in a recent year. Only the choicest of tobaccos are considered suitable for cigar making. While originally cigars were made entirely by hand, recent years have seen the development of machines that carry out every detail of the process with uncanny speed and precision. The better grades of cigars are still handmade, especially in the great factories of Havana, Cuba, from which come the world's finest examples of the cigar-maker's craft.

The cigar maker, sitting at his bench, takes a sufficient amount of "filler" tobacco in his hand, places it on a leaf or "binder," and rolls it into a rough cigar. The outer covering, or "wrapper," is carefully cut with a knife and rolled spirally around the cigar, the tip finally being fastened with a sort of harmless gum or paste. These cigars are trimmed to size, inspected, sorted into various grades, and packed in boxes or bundles.

CIGARETTE MAKING

Cigarettes are made almost entirely by machine, some of these mechanisms turning out more than 50,000 cigarettes each hour. Not only do the machines make the cigarettes, but they also print the brand name, count the cigarettes into lots, and pack them into boxes or packages. More than one hundred billions cigarettes are produced annually in the United States.

To be made ready for this type of manufacture, the tobacco leaves are first stripped of their stalks or midribs and passed through a cutter which reduces them to fine shreds. A roll of cigarette paper is fed into the machine. Another device drops just enough tobacco on the paper. Still another device gums one edge of the paper, rolls it over and fastens it. This forms a sort of endless cigarette. Passing from the machine, it moves under a rapidly moving knife which cuts it into regular cigarette lengths. Counting and packaging are rapidly handled by another machine and the cigarettes are ready for market.

Many states and countries contribute their crops for the use of the smoker. Kentucky may produce his pipe tobacco; his cigar may have a Havana filler, with a wrapper from Sumatra; his cigarette may be of Turkish or Virginia tobacco.

The cultivation and manufacture of tobacco and its products is an industry that gives support to thousands of people and through tobacco taxes provides an important source of income for the governments of the world.

Ewing Galloway

CATTLE ON THE RANGES

FOOD FROM FAR AND NEAR

By Ruth Axtell Chalmers

(*Consulting Editor, Dr. Walter H. Eddy*)

FOOD is man's first and most pressing need; the food business is therefore his chief industry. From the wheat fields of the Far North, where the growing season lasts only a few brief weeks, to the regions of the tropics, where there is summer all the year round, men are busy at the task of planting, raising, harvesting, and distributing food. It is an industry with some part of which all of us are more or less familiar. To cover it adequately would require a story of each and every food. We shall touch only on certain basal American industries, like that of wheat, and certain imported products, like tea and coffee, and certain luxuries which have become necessities, like sugar. Three pictures we should carry away from this study of food industries: the first, of the wonderful fertility of the earth, the second, of man's skill in applying Nature's laws, and the third, of the wonder of modern commerce which brings to our tables as everyday supplies articles of food which have been raised hundreds and thousands of miles away.

THE CHIEF PLANT INDUSTRIES

Since plant food is the basis of all that we eat, man's first dependence is on the soil. The farmer is therefore the most important of all industrial workers. Every other worker depends for his very life on the products which the farmer supplies. The farmer in his turn must cultivate his soil with all care and skill, so that it will continue to yield the products on which he depends.

First in the list of plant products come the grains, — wheat, which we shall see turned into flour for bread; corn, used in our country chiefly as food for the animals which will supply man's meat; rice, the grain of the tropics and the principal food of half the world, grown to a considerable extent on the coast and river lands of Louisiana, Texas, California, and Arkansas; and oats, barley, rye, and buckwheat, which are all grown for their different uses in some parts of the United States and Canada. Another type of industry is that of sugar, which we discuss in a later chapter. The fruit crop of the United States is one of the sources of its wealth, as well as of its people's health, for fruit supplies elements in our diet which give needed nourishment as well as pleasing variety. Increasing attention is paid in this country to the raising of nuts. Last of all, vegetables are among our most varied and staple products, being raised all over the country on a small scale as well as a large.

ANIMAL PRODUCTS

Animals eat plant foods and combine them in their bodies into animal foods on which man depends for his nourishment. How they do it you will find discussed in the story of "The Wonder of Life."[1]

Our meat comes from the flesh of cattle, hogs, and sheep, the raising of which is an enormous industry or group of industries. Cattle raising was one of the most picturesque and interesting early occupations in this country, and is one of the most important of our present ones. It is the source for the raw product on which is built another of our great modern industries, that of meat packing. No one can speak of any of these great branches of the food business without running into figures of hundreds of thousands and millions, either of hogs and sheep raised for slaughter, or of cattle grazing on the ranges before they are sent to the stockyards, or of dollars invested in what is one of the keystones of modern business. Along with the raising of cattle for meat is the great business of dairying, which is extremely important in a country where we are as dependent on milk and butter as in the United States. Poultry and eggs make other chapters in the story of animal products.

INCREASING VARIETY IN OUR CROPS

The United States is one of the few countries able to produce sufficient food to supply the needs of its people, and the variety of its crops is constantly increasing. As a people, we are quick to accept the new, and eager to try the unusual; we are not satisfied with the staples alone, but demand for everyday consumption many of the food-stuffs which were considered in the class of luxuries not long ago.

The government, for our benefit, is constantly making efforts to add to the kinds of crops produced within our borders, by sending out scouts to the far corners of the earth. It is their mission to seek out new fruits and vegetables which seem adaptable to conditions in this country, and bring them back to be tried out in government experiment stations.

The farmer and the large-scale producer also, with the adventurous spirit and clear vision of the true pioneer, have contributed richly to our choice of fresh fruits and vegetables, putting before us in whatever part of the country we may live, products which were rare or practically unknown a decade or two ago. A glance around a city market will reveal an amazing number of products which our grandmothers knew only by name or not at all. Until quite recently the word "vegetable" brought to mind potatoes, onions, carrots, turnips, squash — those standbys used for centuries; now the picture is bound to include such varieties as broccoli, artichokes, endive, Chinese cabbage, and many others — all foreigners originally, but now cultivated more and more extensively in this country.

IMPORTED FOODS

Although we live in a land of unexampled plant and animal wealth and have been wonderfully successful in producing variety as well as quantity of food materials, we still turn to distant parts of the world for some of the special luxuries which add romance to the business of eating. Standing in fascinating array on the shelves of any fancy grocer's will be seen unique offerings from far places, ready to lend their glamour to our dinner tables. It is most interesting to know something of their histories.

France, for instance, sends us truffles, the finest in the world. These are a fungus growth, developing underground, and are located for gathering by trained dogs or hogs. Truffles are raised to some extent in California and other parts of the United States; but it is the Périgord truffle, named for the former French province where it originated, which has achieved special fame. From France, too, comes *foie gras*, a preparation of the livers of specially fattened geese raised near Strasburg and Toulouse. This same country furnishes us with the choicest marrons, large, plump chestnuts preserved in syrup.

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[1] See "The Cycle of Life," Volume Ten, pages 46–49.

Caviar, the roe, or eggs, of the sturgeon, is a Russian delicacy which we prize.

India gives us chutney, a rich pickle which we have never been able to duplicate. It is made from mangoes and other oriental fruits and spices. From China come delicious preserved fruits and ginger; and honey of rare flavor is an offering of Syria, Greece, and Russia.

Spanish olives are famous; and the fine cluster raisins which have long been associated with our Christmas and Thanksgiving dinners are Malagas, from Spain also.

Almost every one of the European countries has its own distinctive cheese which we have never been able to reproduce exactly. Some of these cheeses are described on page 305 of this volume.

Varieties of nuts which we ourselves do not raise are sent to us from different parts of the world — pistachios from the Mediterranean countries, castanas or Brazil nuts from South America, cashews from the West Indies.

Irish oatmeal is another of the foods on our list of importations, for the oats of Ireland are thought to be a little more plump and richly flavored than any others on account of the rich soil and humid climate in which they are grown. England is famous the world over for its biscuits, and we import a large quantity, even though our own production in this line is tremendous. Bacon, cured by a process which gives it an exceptionally fine flavor, is a specialty which we are glad to accept from our neighbor, Canada.

Even the waters of famous springs, Vichy and Apollinaris for example, are counted among the luxuries which we import.

Ewing Galloway

PACKING PERSIMMONS IN JAVA

This kind of persimmon is picked and shipped while it is still hard.

MEAT PACKING

THE United States raises more livestock and consumes more meat than any other nation in the world. The quality is excellent, and the methods which have been developed have proved so successful that they have been adopted in many other countries. The meat-packing industry, which includes every part of the business from buying the animals through the processes of slaughtering, dressing, and selling the meat, and manufacturing by-products, is third in importance in the country, according to the value of the output. In a single year it reaches over $3,000,000,000. Canada also is extensively engaged in meat packing, the industry ranking fourth in the Dominion.

At the head of the list of meat products which we produce comes pork. During a recent year the total output, including lard, amounted to more than 10,000,000,000 pounds. Beef came second with an output of 7,000,000,000 pounds. Over a billion pounds of veal were marketed in this same year, and about half a billion pounds of lamb and mutton. The amounts differ from year to year, but the various meats have for some time stood in this same order.

The meat-eating habits of the people of the United States vary greatly in different localities. In large cities the consumption of beef is likely to be much higher than in country communities. Pork is the staple of the rural districts, and it is the most popular meat in the South also. Then, too, different nationalities living within our borders influence the demand for certain kinds of meat in a community.

THE PRODUCTION OF LIVESTOCK

Livestock production, like every other development in this country, at first centered in the East, but with the westward trend of the population it, too, moved toward the West. This section of the country is to-day the great livestock center of our nation. The corn belt, with its abundance of fodder, plays a most important part in the industry. Not only is much livestock bred and raised here, but this section is a fattening, or "finishing," center for animals raised in other places. The great plains west of the corn belt, where rainfall is not sufficient for ordinary cultivation, are used extensively for the production of cattle. Millions are raised on these plains, many of them being brought to maturity in the richer lands of the corn-producing area. The West is being more and more divided into ranches, and fenced; the day of the cowboy who figures so picturesquely in early Western life and about whom so much of our fiction has centered, is passing.

The Appalachian and Great Lakes regions form another cattle-raising area, and the cotton belt of the South a fourth. Small farms throughout the country also contribute largely to the total production.

Beef animals are usually ready to be fattened at the age of two or three years, but there is an increasing tendency to get the cattle ready for slaughter when they are twelve to eighteen months old. In this "baby beef" industry, the cattle are usually bred and finished on the same farm, although farmers sometimes buy calves to make up their herds. High-grade cattle and plenty of high-grade feed are needed for the production of baby beef. In sections where agriculture is so highly developed that little land is left for pasturage, the baby-beef development has resulted in economy, for the total feeding period is so shortened as to over-balance the greater cost of the feed. And, although the younger cattle weigh less when they are marketed than the older animals, they produce a larger percentage of meat. However, where there is plenty of land for grazing the older method of raising livestock is the more practical.

The hogs on the farms of the United States and Canada are worth millions of dollars, as much as all the gold dug out of the earth. The Western corn belt is our great hog-producing section. Here it is a common practice to allow the animals to follow the cattle and eat the grain which would otherwise be wasted. Or they may be turned into the cornfield and allowed to harvest the crop. This is called "hogging down the corn." Another method of fattening hogs is to keep them in open pens, with hoppers of corn always before them. While hog raising is not carried on in such a large way in the East, there are establishments where the number of hogs kept runs into the thousands. In many places the Eastern farmers depend on garbage from large cities for food for hogs.

INSPECTING AND MARKING BEEF IN ONE OF THE LARGE SLAUGHTER HOUSES

The raising of sheep for meat is a much less important business than the other livestock industries, but the production of lamb and mutton has greatly increased in the last half century. Sheep raising on the Western plains has diminished as the best of the lands have been taken up for farming, but there is still much grazing on the open ranges. The sheepmen have been pushed back to the rougher and more arid lands, moving from place to place with the changes of the seasons. The sheep from these ranges are often fattened in the corn belt or on irrigated lands farther west. In the corn belt they are allowed to clean up the standing crop, stalks and all. West of the Mississippi where there is little stormy weather, the sheep are fattened in open pens. In the East the fattening is more often done in barns. Throughout the country there are farm flocks which make profitable rough lands which would otherwise be of little value.

THE STOCKYARDS

To handle all this livestock when it is ready to be turned into meat, a remarkable system of stockyards and packing houses has grown up. Canada has a similar system. Chicago is the greatest meat-packing center in the world, with Omaha and Kansas city next in importance in the United States. Important packing houses in Canada are located in Toronto, Winnipeg, Edmonton, and other large cities.

Livestock, consigned to commission men, is shipped in special cars to the stockyards. The commission man acts as the shipper's agent, transacting business with buyers from the packing houses. The animals are sometimes shipped directly by the farmer, but more often they are bought up by men called "country buyers" who take charge of the transportation and resell through the commission men at the packing center. Many shipments are at present handled by cöoperative associations made up of a number of individual raisers of livestock in a certain district. In some cases the packers send their buyers into the country to buy at the farms for direct shipment.

The leading stockyards, which, like those at Chicago, cover scores of acres and employ thousands of people, are really huge, modern manufacturing plants. They include not only an elaborate system of animal pens with their runways and alleyways, but buildings where the animals are slaughtered, the meat dressed, and by-products manufactured.

Through the stockyards passes a steady procession of cattle, hogs, and sheep. The daily output, made possible by efficient methods and modern labor-saving equipment, is tremendous. The slaughtering and dressing is a matter of only a few minutes, while in less than an hour from the time when a steer enters the slaughter house the carcass is ready to be passed on to the refrigerator room, or cooler. The carcasses, suspended from overhead tracks, are kept moving along from one worker to another. Each one performs with almost incredible rapidity some one part of the whole operation.

Courtesy of Food Industries

FILLING SAUSAGE CASINGS

Sausage is an important packing-house product.

After the carcasses are dressed they are sent to coolers where they remain until they have lost all their animal heat. Then the meat is loaded into refrigerator cars and shipped to all parts of the country, some of it to travel from the seaport cities to foreign lands. A small amount of meat is shipped directly from the packer to the dealer, but the greater part of it is handled through branch houses or wholesale establishments.

Beef, mutton, lamb, and veal are, as a rule, shipped as whole carcasses or sides. Much of the pork produced is cut at the packing houses and certain cuts cured before shipment. "Curing" means smoking, salting, or pickling in brine, processes which enhance the keeping qualities of the meat and give it a distinctive flavor. Ham, bacon, salt pork, dried, or "chipped" beef, and corned beef are examples of cured meats.

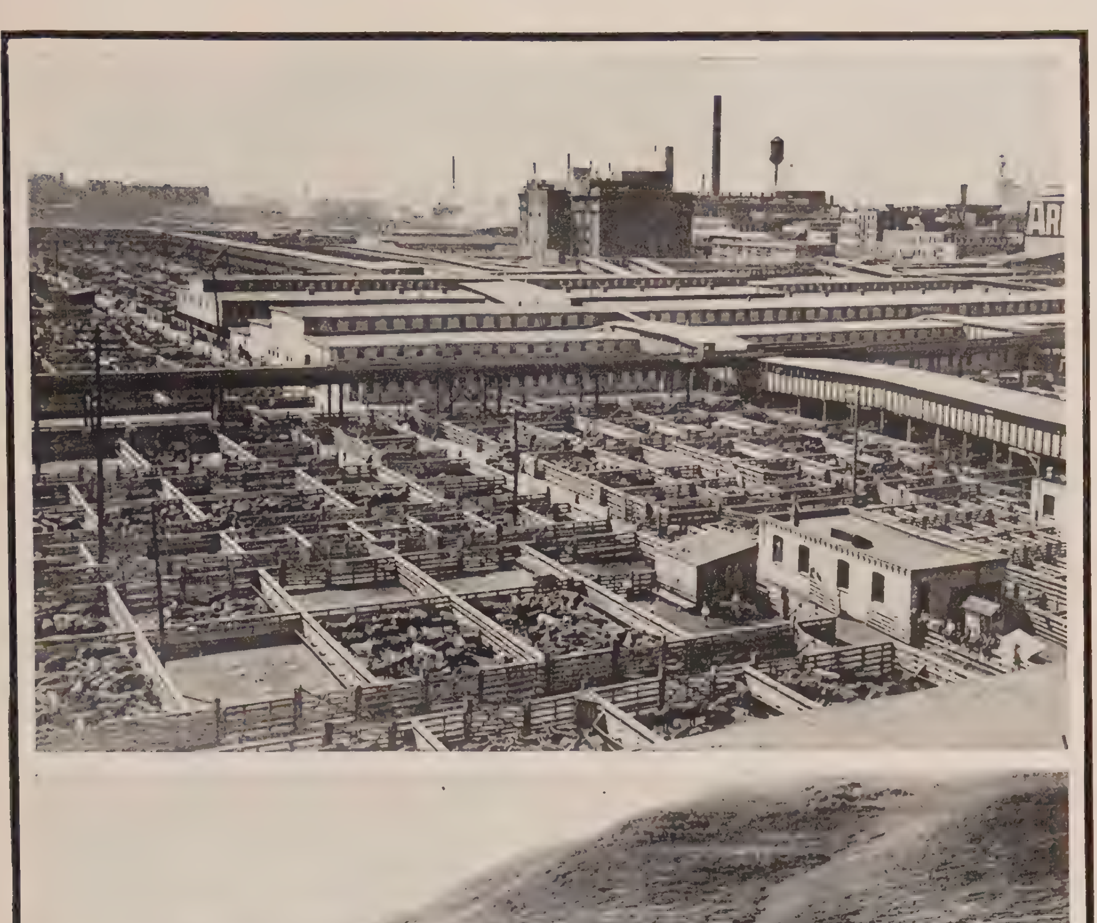
Canned meats, also, are an important product of the packing houses. Many different varieties, from roast beef to pig's feet, are included.

A recent development in the meat industry is the production of packaged meats. Roasts, chops, steaks, and other cuts, all ready for cooking, are attractively boxed and labeled, making it possible to buy meat by brand.

The total productivity of the packing industry has been greatly increased by the invention of ways to utilize every part of the animal from bones to hide. It is often said of the pig that nothing is lost but the squeal. The list of by-products is tremendous. Lard, tallow, oils, and soap, bristles for brushes, material for buttons, combs, and knife handles, fertilizers, glue, serums for laboratory use, casings for sausages — these are a few of the many products which come ultimately from the packing houses.

By no means all of the meat produced in this country is handled in the large packing houses. There are smaller packing centers in different parts of the country; in many places butchers buy live animals and slaughter them for their own trade; and there is still much meat produced on the farms. Pork, in particular, is a farm meat, raised in many communities on a small scale simply for home consumption.

The activities of stockyards and packing houses are under very strict government supervision. All animals are inspected before they are slaughtered, and the meat is thoroughly examined before shipment. The purple mark often seen on the outside of the meat we buy is the inspector's stamp. All meat which is shipped in interstate or international commerce is subject to federal regulations; this covers about sixty-five per cent of the total production.



Ewing Galloway

FROM RANGE TO STOCKYARDS

Above: A view of the Chicago stockyards, the largest cattle market and packing center in the world. Below: Beef cattle in corrals on a South Dakota ranch.

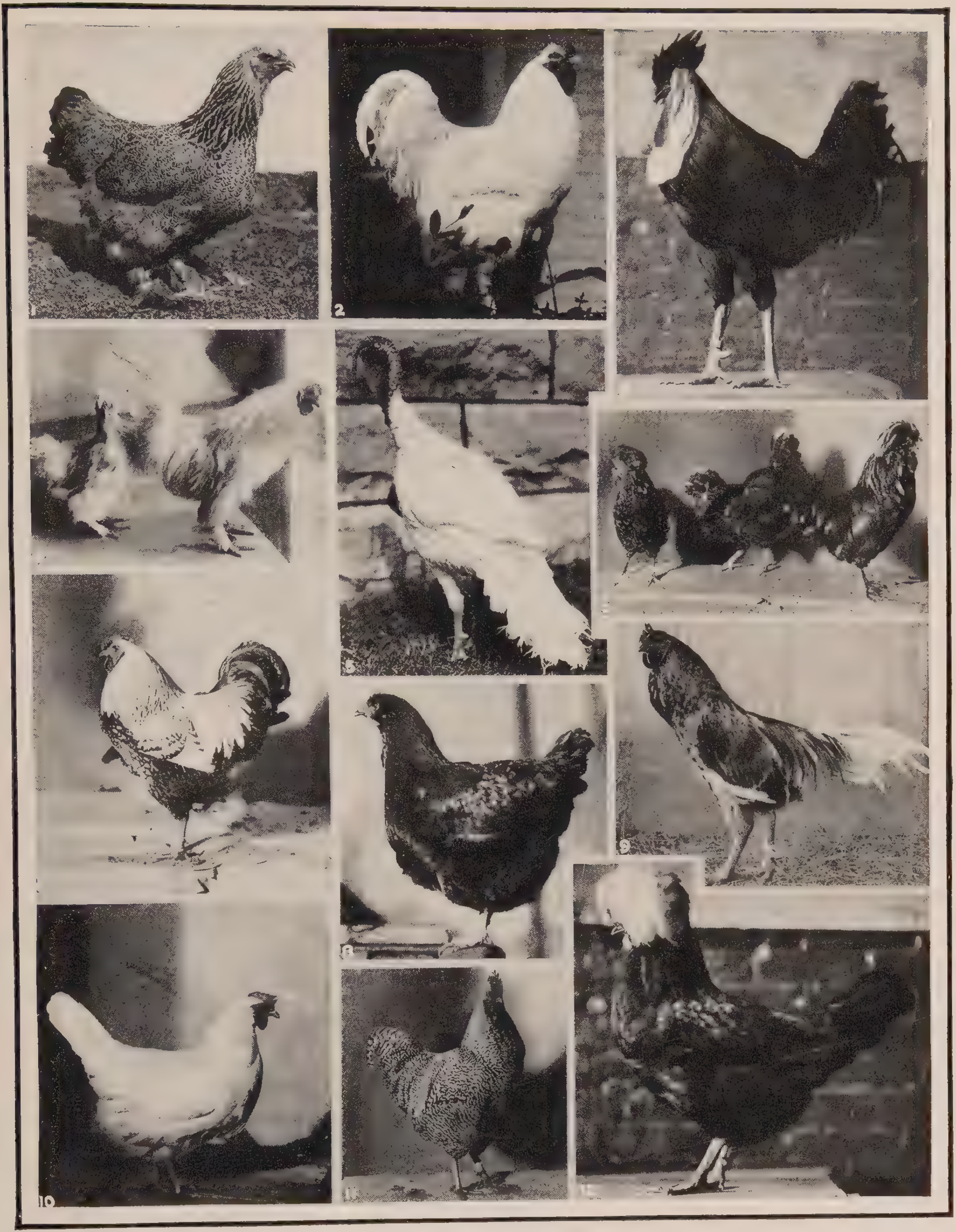
POULTRY RAISING

UNTIL the second quarter of the nineteenth century there was no great demand for poultry, as wild fowls were plentiful. Poultry raising was merely an incident in farm life, and eggs and chickens were regarded more or less as by-products. Since that time, poultry raising has developed rapidly into a business of vast proportions. Chickens are by far the most important of the domestic fowls, making up about ninety-six per cent of all the poultry marketed.

The Middle West, where grain is cheapest, is the greatest poultry section of our country. Although there is very little large-scale production here, practically every farmer keeps hens, and both eggs and dressed poultry are marketed through central organizations. In many of the packing plants special fattening establishments have been built. The birds are collected from the farming districts in which they are raised and are fattened in small coops where they are fed generously and have no chance for exercise. Milk is sometimes included in the feeding to give the flesh an especially fine flavor and quality, and the birds are then marketed as "milk-fed" chickens. The chickens are dressed at these plants, chilled in huge refrigerators, and shipped in refrigerator cars, often to distant markets. There is a vast business in poultry done also by the smaller farmers who sell directly to the wholesale, and even to the retail markets.

In the East, in the districts near large cities, and on the Pacific coast, the industry has developed along commercial lines. In one city in California, Petaluma in Sonoma County, a million fowls are kept, and elsewhere there are extensive farms devoted exclusively to poultry. The Eastern market has been made available to Western poultry dealers by modern methods of refrigeration and transportation. So perfectly does poultry keep during the trip across the continent that the Western product can compete even in Eastern cities with home-grown birds. California, for instance, produces

FEEDING DUCKLINGS ON A NEW ENGLAND DUCK RANCH



TWELVE BREEDS OF POULTRY

1. Dark brahma. 2. White Plymouth Rock. 3. White-faced black Spanish. 4. A pair of silkies. 5. White Holland turkey. 6. Houdan cock and hens. 7. Silver wyandotte. 8. Buff Orpington. 9. White-laced red Cornish. 10. White leghorn. 11. Barred Plymouth Rock. 12. White-crested black Spanish hen.

a large amount of poultry beyond the local requirement and is thus enabled to dispose of it to advantage.

Hatching baby chicks is an interesting branch of the poultry industry, and is conducted to a considerable extent as a separate business. Incubators have been invented which take the place of the natural method of hatching eggs, providing conditions of heat and moisture similar to those of the nest. Heated brooders, or hovers, are employed to keep the baby chicks warm during the early days of their lives when they would ordinarily be cared for by the mother hen. When they are old enough, the little chickens are shipped to farmers and poultry plants. By artificial incubation a tremendous production of baby chicks is made possible. The capacity of some of the hatcheries is over a million eggs, and altogether 300,000,000 chickens are hatched in this way in a year.

Duck raising is a highly specialized industry, and there are a number of duck farms in New England and Pennsylvania and on Long Island, where from twenty to fifty thousand ducklings are raised each season. White Pekings are used exclusively and are expected to weigh six pounds when ten or eleven weeks old. They are called "green ducks" when marketed at that age and command high prices.

Unlike ducks, geese and turkeys are raised entirely on general farms. There are men in several parts of the country who gather up from ten to twenty thousand geese in the late summer and fatten them for the Christmas trade. Each season several carloads of these birds are shipped to the States from Prince Edward Island, Canada. The cars are fitted with platforms, one above another, and nearly fifteen hundred birds are crowded into a car. Raw potatoes are spread on these platforms and give the geese both nourishment and water while they are on the journey. After the birds are unloaded, they are driven to the fattening farm.

The turkey is a native of North America, found here by the Pilgrims who came on the *Mayflower*, and served at the first Thanksgiving dinner. The bird has been domesticated and is now raised in many parts of this country and in Europe as well. It is less hardy than the other domestic fowls, and the young must be carefully protected from cold and dampness.

THE MARKETING OF EGGS

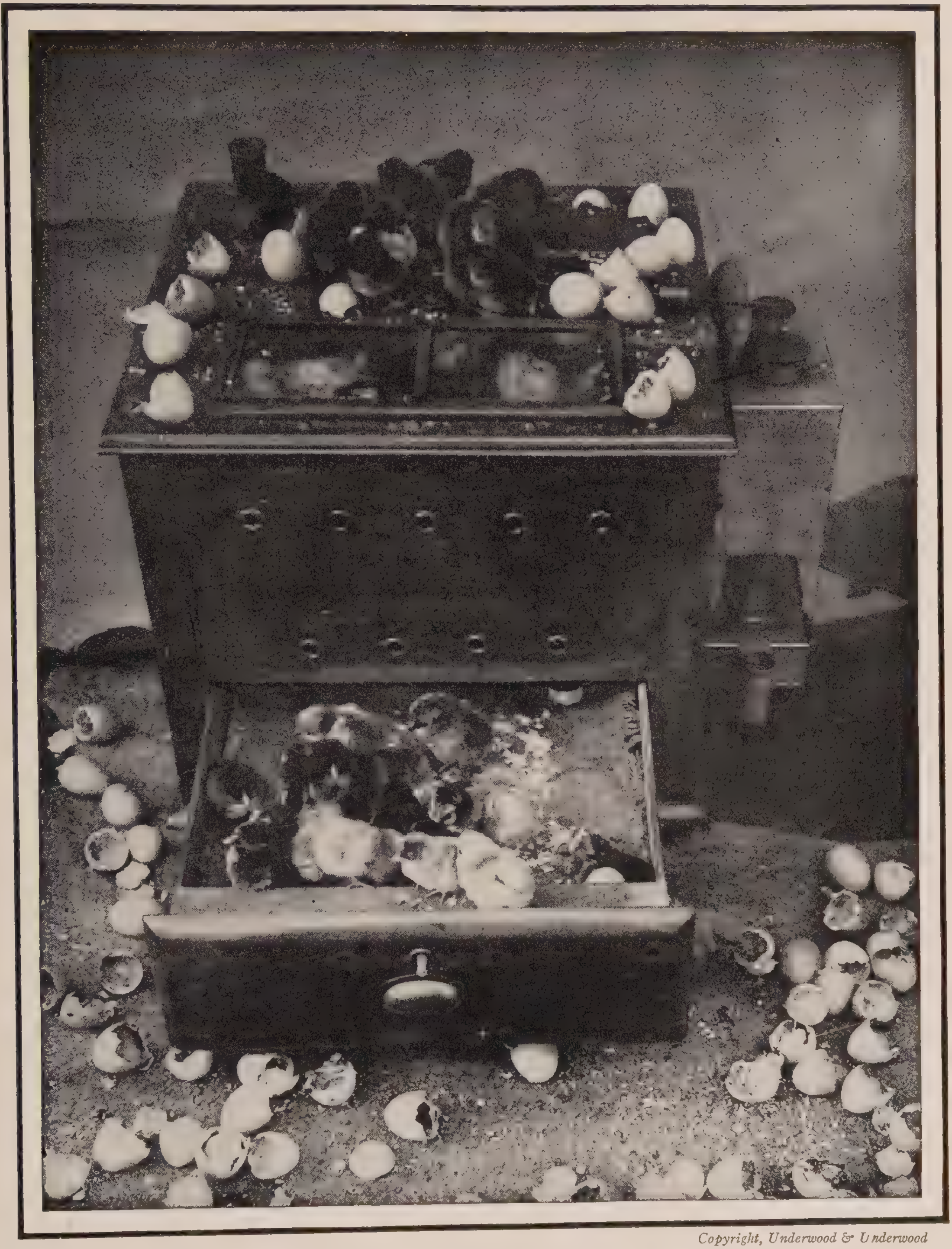
Egg production is a more important part of the poultry industry than meat production. When we in this country speak of eggs, we invariably mean hen's eggs, for these are the only ones which we use to any extent. In England and Holland ducks are raised for their eggs. Much has been learned in recent years in regard to the breeding, feeding, and care of hens. Application of this knowledge has led to increased egg production. In spite of the numerous large poultry plants which have grown up, by far the greatest number of eggs produced are accumulations from general farms.

In the large establishments through which eggs are marketed, they are very carefully examined and graded. They are first sorted by their exterior appearance for size and cleanliness, and then they are "candled." Candling is an examination in front of a light, and to an experienced eye it reveals the condition of the interior of the egg. A skilled worker can tell at a glance whether or not an egg is fresh, whether it has been fertilized, and can see spots of mold which sometimes form in eggs. Eggs that are cracked or undersize or have dirty shells are opened, and then frozen or dried. In this condition they will keep perfectly for a year or longer, and are sold to bakeries and to factories where salad dressing, noodles, and other foods containing eggs are manufactured.

The eggs that pass the candling test are held in cold storage at such a temperature that the original condition is retained. A cold-storage egg that has been kept for nine months or a year may be in better condition than one only a few days old which has been left too long in a warm nest or exposed to heat during transportation.

Poultry farms which specialize in strictly fresh eggs often stamp each egg with a name or trademark.

It has been estimated that there is an annual loss of millions of dollars due to careless handling of eggs in packing and marketing. The total production of eggs in the United States is approximately 2,000,000,000 dozens annually. In addition to all that we raise we import many in frozen or dried state from China. These are used for commercial purposes.



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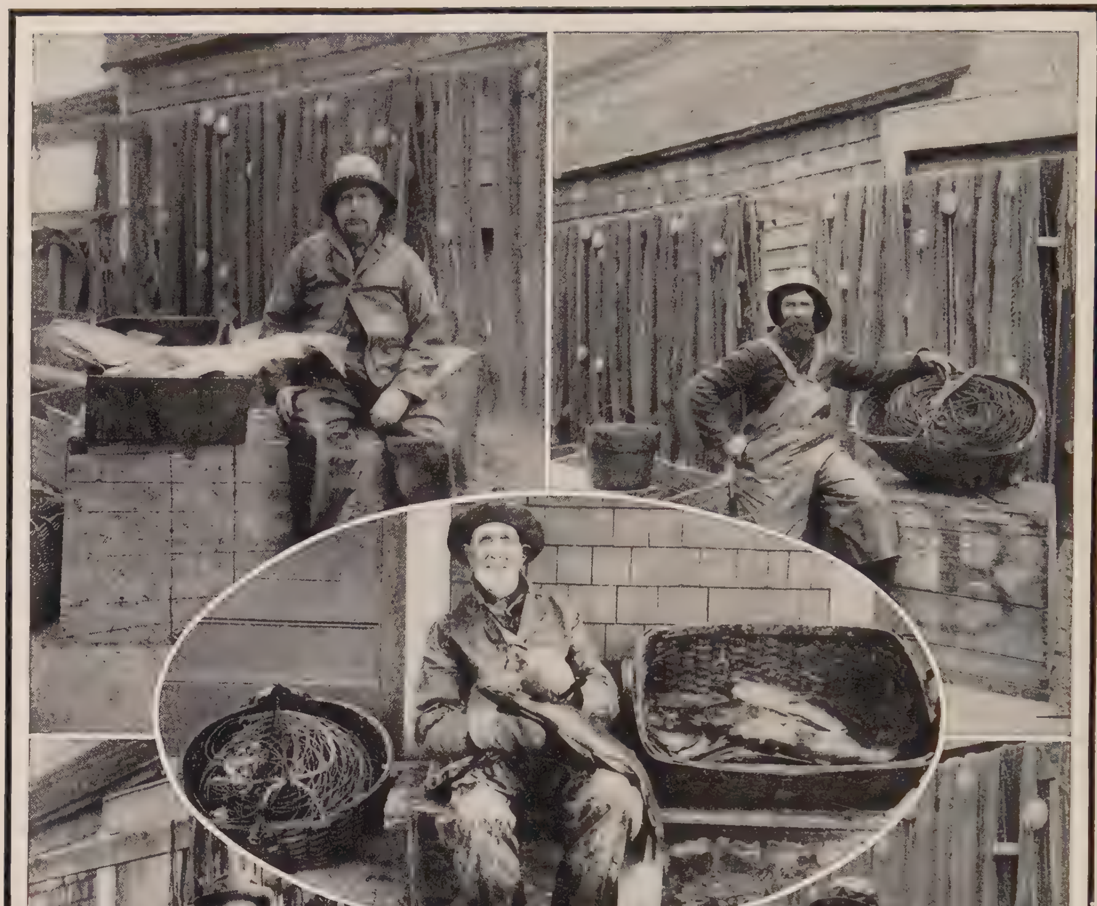
A SMALL INCUBATOR WITH THE CHICKS COMING OUT OF THE SHELLS



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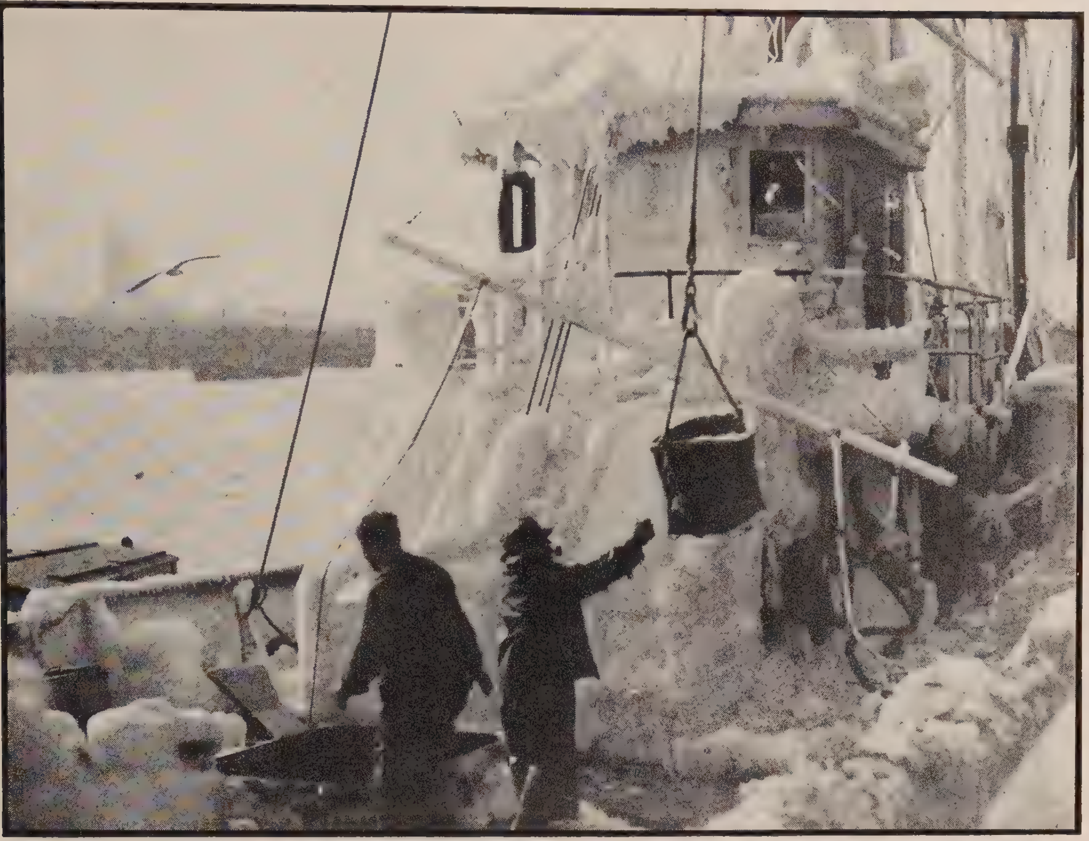
A GROUP OF OLD-TIME GLOUCESTER FISHERMEN



Keystone

BACK FROM A WINTER FISHING TRIP

FISHERIES

FISHING is a sport that never grows old. From the time the boy dangles a bent pin from the end of a cotton string to the time he weighs the respective merits of the "Doctor" or "Scarlet Hackle," its charm never weakens. Surmounting every failure is the chance for future success, and in this elusiveness lies the universal lure. But fishing as a sport and fishing as a means of livelihood are two very different things.

In early days, man turned naturally to fishing and hunting as his chief defenses against hunger. Gradually his crude equipment gave place to the improved tackle devised by modern ingenuity. He learned, too, what fish frequented sea and stream; when the best season was to capture them; what bait was most successful; and to what uses his catch could be turned when hauled in. Fishing, in short, became an industry. Certain branches of it were followed by one set of men, certain branches by another. Cod, salmon, herring, and deep-sea fishing, as well as the trade in scallops, clams, lobsters, and crabs, were all taken up by men skilled in their particular craft.

COD FISHING

Along the eastern coast of North America, for instance, are hundreds of men whose livelihood is entirely dependent on the perilous occupation of cod fishing. Soon after the sealing season closes in April, fleets of small vessels make their way to the neutral waters off the Grand Banks of Newfoundland. Many of these schooners come from Canada, many from Maine and Massachusetts coasts, some from France, and some even from Holland. Often

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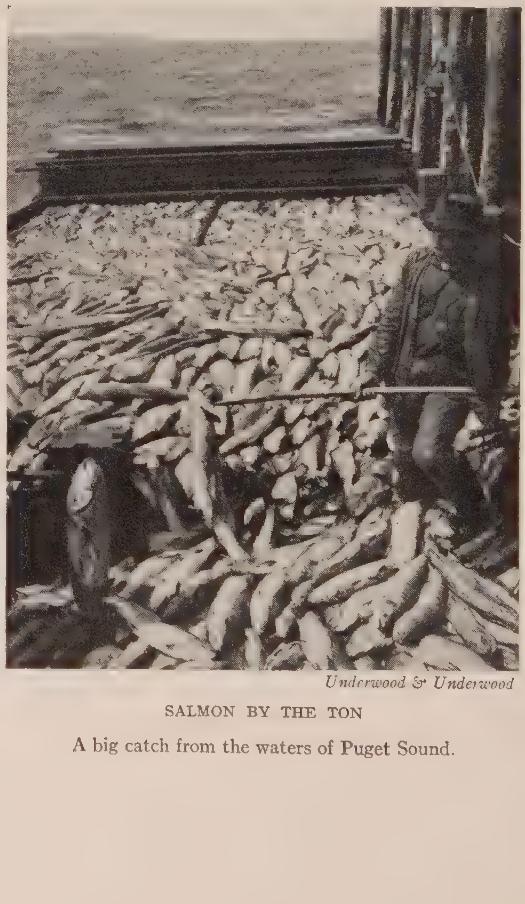
DRYING COD AT GLOUCESTER, MASSACHUSETTS

The fish, split and salted, are spread out in the sun.

in the season there are as many as seventy-five hundred schooners, cutters, and yawls anchored on the fishing grounds. Each ship carries six small dories which can put off alone, and in this feature of the occupation the great danger lies. Frequently sudden fog or darkness shuts down on the fleet and the dories lose their bearings, or are perhaps overtaken by storms and driven out to sea; sometimes the little bobbing cockle-shell, top-heavy with a big catch, is swamped by a wave. Cod fishing is done either by a hand line, by trawl, or by gill-net. When it is done with a line the fishermen go out singly. Trawling, on the other hand, requires two men — one to scull the boat and one to handle the tackle. The trawls, marked with their owner's flag or color, are carefully set, and later dragged up by the buoy line. Usually from two to three hundred fish — mostly cod — are found inside. Live capelin (a variety of smelt) or tiny cod are used as bait. After the trawls have been cleared and re-baited they are again sunk, being carried to the bottom by two small anchors. The gill-net, set with flag-bearing buoys, is to all appearances like the trawl; the nets, however, are set at different angles and are intended for catching cod after the line fishing of the year is at an end.

The cleaning and salting is generally done at night, after the catch has been put aboard the vessel; during a season when the haul is large the men sometimes work all night, changing their posture frequently that they may not drop asleep. Sometimes, however, a collecting ship, equipped with ice, goes about among the fleet, and, after taking the haul aboard, steams back to the market with it. When it is possible, the fishermen put in to shore, where the split, salted cod are dried in the sun on wooden stages.

The superiority of steam over sail power made itself felt in the fishing industry as early as 1878. To-day, the need of our cities for fresh fish has brought about the development of great fleets of steam trawlers, which daily bring in millions of pounds of fish carefully packed in ice. Not only are these vessels propelled by steam, but steam is also used to raise the huge nets with their burdens of sea food. The nets used in this type of fishing are called "beam" trawls. They are large bag-shaped nets. The larger end is



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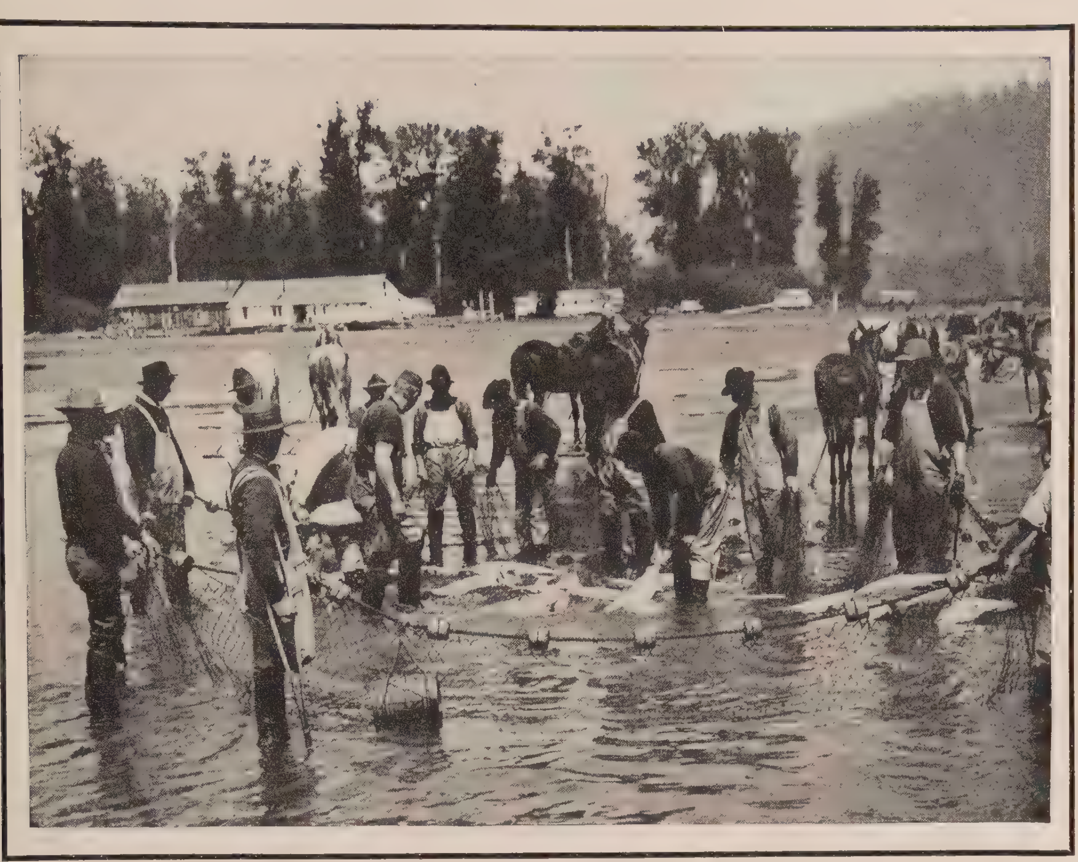
SALMON BY THE TON

A big catch from the waters of Puget Sound.



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SEINING SALMON ON THE COLUMBIA RIVER, OREGON

held open by a beam supported on iron runners. As the nets are dragged over the bottom of the sea, the fishes are swept into the smaller end, which forms a pocket from which they cannot escape. Each trawler usually carries two nets, which are dragged in turn for about six hours each. As the empty net is lowered, the full net is raised to the deck, so that the men are constantly employed sorting and packing the fish. Fishing is carried on day and night, and the boats steam rapidly to port as soon as a cargo is secured.

HOW SALMON ARE CAUGHT

On the western coast of North America, both in Canada and the United States, are extensive salmon fisheries. Great numbers of these fish each spring enter the Columbia and the Fraser rivers and Puget Sound, and amid the riot of the swollen waters make their way upstream, moving near the center of the current and keeping close to the surface. This fishing lasts about five months and is done chiefly with trap-nets or gill-nets strongly made to meet the great strength of the salmon. On shore the fish are dried and salted, or are sent away for canning.

SWORDFISHING

The swordfish, while not sufficiently abundant to be the object of regular fisheries, is caught in many parts of the world. These huge fish, with their long sword-like beaks, sometimes reach a weight of five or six hundred pounds, and are greatly favored because of their delicious flavor. On the New England coast, small sailing vessels search for them during certain seasons. Platforms, or "pulpits," are built on the bowsprits of these boats. The fisherman stands in the pulpit, armed with a harpoon to which a strong line is attached. When the boat approaches its prize, the harpoon is plunged into it. After it has been killed, the fish is hoisted on board.

On the coasts of Greece and Sicily, swordfish are often caught in strong nets as well as with the harpoon.

OTHER FISH IN SALT WATERS

Herring, one of the big catches of the New Brunswick, Maine, and Massachusetts coasts, are taken in weirs at night, and afterward brought to shore and dried and smoked in bronzed houses like those so frequently seen throughout the Nova Scotia country. The eastern coast of New England is rich, too, in mackerel, bluefish, swordfish, and sea-bass. From Cape Cod to the Delaware River there are numerous oyster beds, and during the winter months many scallops are taken from this region by means of dredges. Lobsters, clams, and crabs have also an important place in the fishing industry.

The South has its mullet grounds off Cedar Keys, Florida, where the season lasts from December to March. These fish are caught in great quantities in purse-seines, gill-nets, or trawls. The Gulf of Mexico is also the home of the red snapper, held in high favor by the Southerners, and caught with hand lines from dories. Instead of icing these fish, however, they are put in tanks constructed aboard the vessels and are kept alive until handed over to buyers. A great variety of smaller fish is caught off our shores, to say nothing of the trout, bass, perch, pickerel, and landlocked salmon captured in our inland rivers and lakes. The United States Fish Commission has many stations where both fresh- and salt-water fish are hatched and shipped all over the country for the restocking and preservation of the fish industry.

A great number of the species of fish found off the American coast are also found in foreign waters. Norway has extensive salmon and lobster fisheries; England catches great numbers of herring and pilchard, a sort of gypsy herring, the smallest of which are shipped to Italy for the sardine trade. Sturgeon is found in England as well as off the North American and Russian coasts. The Mediterranean countries have vast anchovy fisheries as well as good catches of mullet and dory, the latter a gold-hued fish frequenting southern waters. Maigre, pilot-fish, sharks, saw-fish, and the tuna, or tunny, are all natives of the Mediterranean.

Tuna fish abound also along our Western coast, and the catching and canning of them have become an important industry in California. These fish grow to an enormous size, weighing up to fifteen hundred pounds, but it is the younger, smaller ones, averaging about thirty pounds, that are most used. Very little fresh tuna is marketed; practically the entire output is in canned form.

In China the fishing is frequently done by the aid of a cormorant, a bird accustomed to diving into the water for its food. These birds are taken when young and a tight metal band is put round their necks; to this collar a line is attached and the bird is trained to dive and deliver up his catch.

SHELLFISH

ALL along our seacoast, in sections where there are sheltered coves and inlets, and in the more open waters a little farther from shore, two important classes of fish, the mollusks and the crustaceans, abound. These we know better by their common name of shellfish. To the mollusk family belong clams, scallops, and oysters; lobsters are the most familiar of the crustaceans.

CLAM DIGGING

Clams are of two general classes, the hard, or quahaug, and the soft clam, or steamer, as it is sometimes called. The hard clam is almost round and is known by many different names, depending on its size. The soft clam is more elongated in shape. It stays buried in the sand, breathing through a long tube which reaches up to the surface. When alarmed, it draws in this tube suddenly, and water squirts out. By watching for this spurt of water it is easy to locate the clam. Hard clams are the variety served raw on the half shell, and the quahaug is also excellent for chowders; soft clams are steamed, and the larger ones used in chowders and for cooking in other ways.

Wide World Photos, Inc.

A GIANT LOBSTER

Soft clams are dug at low tide, when the sands are gone over thoroughly with shovels or pitchforks, or, where there are large areas to be covered, by man- or horse-drawn rakes. Hard clams live in deeper water and are gathered with special dredges.

The razor-back clam of the Pacific coast is quite different. It has a long, narrow shell, suggestive of an old-fashioned razor. Razor-back clams are quite soft and are used almost entirely for canning.

Comparatively few clams are shipped from the seacoast to distant inland places, but the canning of clams has grown into an industry of considerable importance.

HOW LOBSTERS ARE CAUGHT

Lobsters abound along the Atlantic coast all the way from Labrador to Delaware, and are particularly plentiful off the coasts of Maine and Nova Scotia. They are caught in "pots" which are placed in the water by the fishermen at points known to be most favorable. Heavy weights hold them in place, and a cord is attached by which to pull them up. The lobster pot is a slatted trap, having a funnel-shaped opening into which the lobster is attracted by bait and from which it is unable to escape. Lobsters are collected alive and are usually shipped alive, on ice. Until they are cooked, lobsters are of a dark greenish color; then they turn to the brilliant red which is so familiar.

The demand for lobsters has been so great that there has been danger of their being exterminated. The government is, therefore, taking measures to preserve and increase the supply by establishing "sea nurseries" where the eggs can be hatched under favorable conditions and the little lobsters given a chance to grow.

THE SCALLOP

The scallop, as it is seen in the market, gives little idea of what it is like when it is taken from the water. It is a large, two-shelled mollusk, somewhat similar to the clam, but very soft and watery. The part which we eat is only the muscle which keeps the shell closed. These bits of solid flesh are separated from the shell, packed in containers surrounded by ice, and shipped to the market.

Scallops are found along the entire Atlantic and Gulf coasts. They are brought up from the ocean bottom by dredging.

OYSTER CULTURE

Most important of the shellfish is the oyster. In the United States the oyster fishery is second only to the salmon fishery. It is conducted in every seacoast state from Cape Cod to the Rio Grande and from Puget Sound to San Francisco, and is valued at over $17,000,000.

Great piles of shells found in many places along our Eastern coast tell of the free use that the red men made of oysters; on the Damariscotta River in Maine, where no oysters are now found, there is a mound containing about seven million bushels of oyster shells. It is said that the Indians along the coast not only depended on oysters for food, but used them, dried and smoked and strung on twigs, as an article of barter with their inland neighbors.

The early settlers of this country considered the abundance of oysters which they found along the shores an indication of the richness of the land to which they had come, for in Europe oysters were, and still are, a luxury to be enjoyed by only a few. The extensive use made of this popular shellfish eventually depleted the natural beds, and it became evident that the supply would fail unless man himself took a hand in cultivating them just as he did his crops.

The oyster, as we know it, is as immobile as the potato, but before it settles down to a stationary life it may have wandered far from its parental home. The embryo oyster, a tiny particle barely big enough to be seen without a microscope, which forms from the eggs deposited in the water by the mother, is covered with microscopic hairs which keep it suspended in the water and give it power to move. It is carried about by tidal currents for a while, but soon the shell begins to form, and burdened by this, the little oyster attaches itself to some firm, clean object on the ocean bottom. If it fails to find anything suitable for its purpose, it perishes.

The men who first undertook oyster culture in America did not know these facts, but they had observed that almost any hard-surfaced object which fell into the water, if it was not buried in mud, became coated with a growth of oysters. They reasoned from this that if such materials were placed in suitable spots oyster beds would develop. The oyster growers began their operations in the shoal waters along shore, then extended them into the deeper, open waters of Long Island Sound and Chesapeake Bay, and to every coastwise state from Massachusetts to Texas and from Washington to California.

There are many hazards to be met in the two to five years which elapse between the time when the eggs are deposited in the water and the day when the oysters are harvested. Perhaps at a critical time some weather disturbance may kill the baby oysters while they are still swimming about. Or there may be so many in one place that they cannot grow, and many die, while those that are left do not obtain enough food or are undersized or misshapen from crowding. Even after the oysters have attached themselves to a surface, they are never safe from the other sea creatures which seek them for food. Freshets from the land may make the

Ewing Galloway

SORTING OYSTERS IN A LONG ISLAND PLANT

water too fresh or too muddy for the oysters to thrive, or storms rolling in from the sea may tear up the oyster beds.

The gathering of oysters was done at first by tonging from sail boats or rowboats; but as the industry has grown these small craft have given place to fleets of motor boats and steamers, equipped with dredges for bringing the oysters up from the ocean bottom.

Oysters are marketed in the shell to some extent, but the greater proportion of them are shucked at the plants to which they are brought from the boats. The shells are opened by hand. Then the soft bodies, which are to be used for food, are taken out and washed in salt water to remove the secretions which would cause them to spoil. After being well chilled, the oysters are packed in iced containers and shipped by express to all parts of the country, being re-iced along the way. Thus they can be kept in perfect condition during a long journey. Oysters are good at all seasons; it is to protect the industry, to allow for a period in which the eggs can be deposited, that we have very few oysters during the summer months.

Since oysters are often eaten raw, it is important that the water in which they live and from which they obtain their food be free from dangerous bacteria. The United States government and many state and city governments have made regulations regarding the growing and handling of oysters. The waters where oyster beds are permitted are frequently analyzed for bacteria, and shipping and marketing conditions are subject to inspection. Because of all this care, raw oysters are now as safe a food as raw lettuce, celery, strawberries, and other foods which have close contact with the soil.

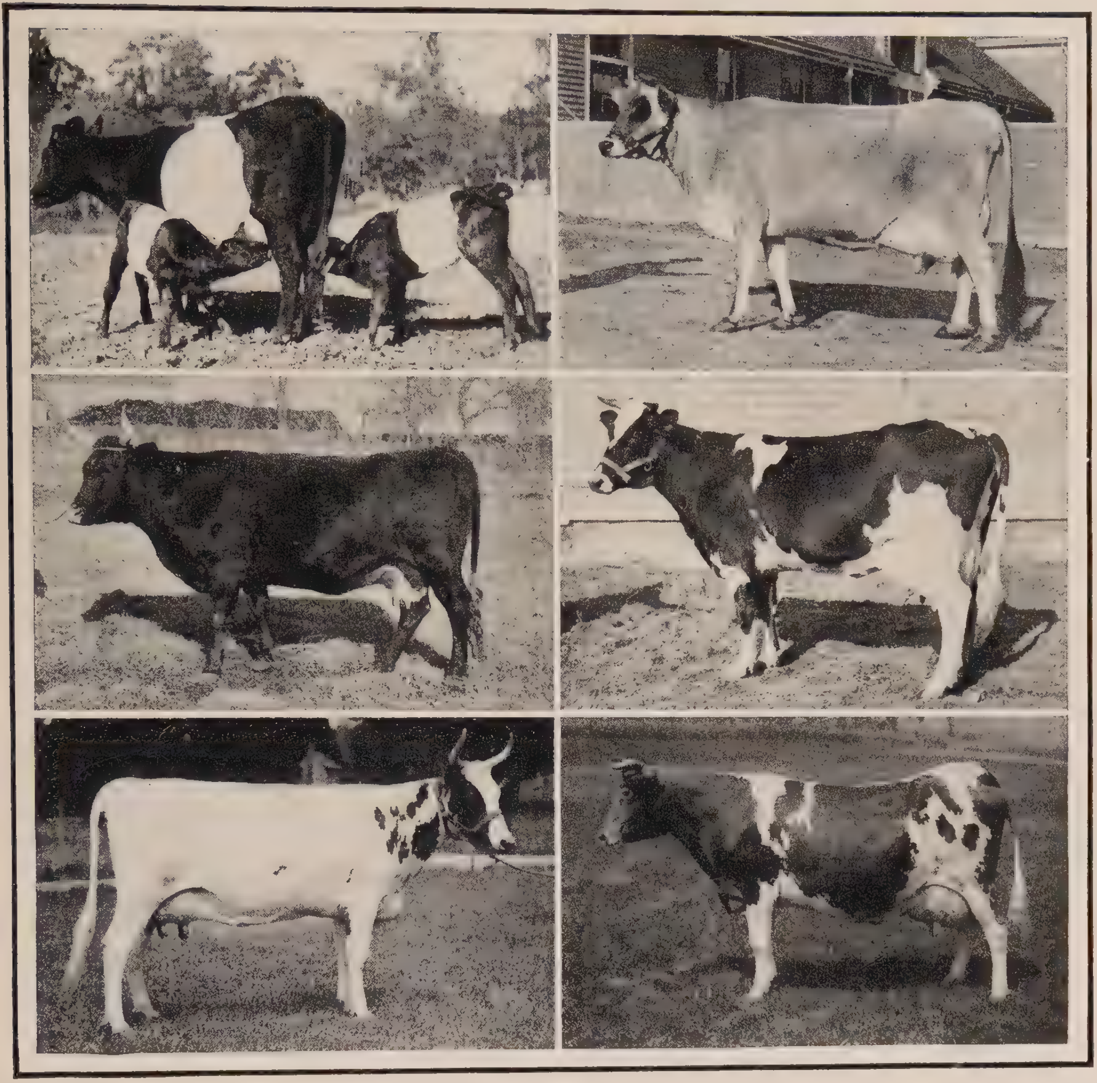
DAIRYING

HAVE you ever thought that next to bread and water, milk is used more commonly than any other article of food and drink? Milk is the first form of human food and the most nearly perfect of all that Nature provides. Throughout history dairy products have been linked with the races that have conquered by their might and excelled by their abilities. "The fate of the white race is indissolubly linked with that of their cattle," Herbert Hoover has said; "they cannot survive without dairy products." There are over twenty-five million cows in the United States, one for about every five persons, and the dairy industry, which is still growing, is valued at over thirty billion dollars.

Of the many breeds of cattle which exist in the world, those most used in this country for dairy purposes are the Jerseys and the Holstein-Friesians. The latter, natives of the Netherlands, are the largest of the dairy cattle and the greatest milk-producing breed. The milk is not rich nor highly colored, but in composition approaches the human product more closely than that of other breeds, and is unsurpassed for general use. Jersey cows, coming originally from the island of Jersey in the English Channel, give milk which, though less in quantity, is exceptionally rich in butter fat. Jerseys are kept especially for butter making and to supply the cream market. Guernseys, from another island in the Channel, are also exceptional butter producers.

Scotland is the native home of the Ayrshire, another important breed. The cows are not heavy milkers but are unexcelled for sections where rough pasture lands must be depended on for food. Swiss cattle are rugged, thrive well on rough pasture lands, and give milk for an unusually long season. Dutch belted cows, so called from the wide band of white encircling their bodies, are well suited to sections where grain is expensive, for they have been found to do best on a light grain ration.

While milk is the most valuable food that Nature gives us, it may be one of the most dangerous, because it is a good food for bacteria as well as for human beings. Everywhere about us there are these tiny organisms, too small to be seen without a powerful microscope, waiting for a chance to obtain food. They find that food in milk. There are hundreds of them in a single drop. As they live in milk, they multiply with amazing rapidity. Where there were hundreds, there are soon thousands and even hundreds of thousands. Then it is that the milk is spoiled and not fit for us to use, for even the bacteria

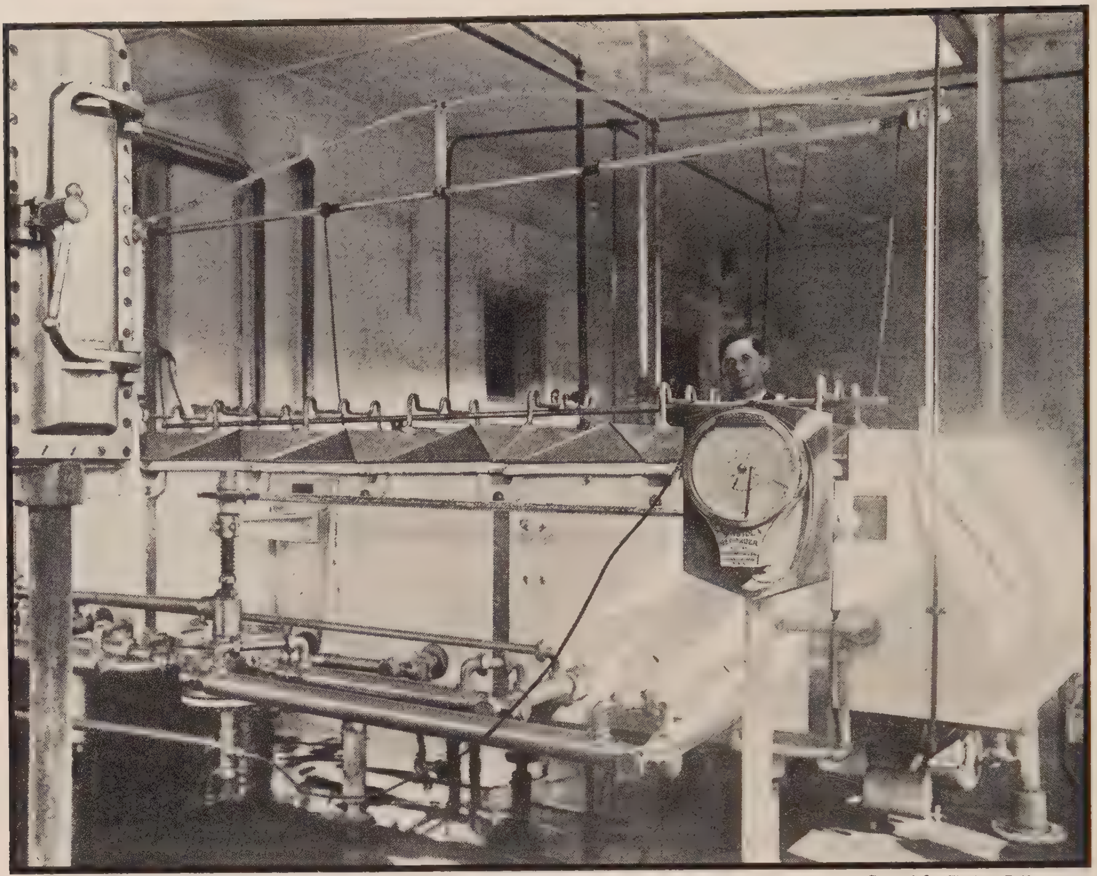


SIX OF OUR COMMON BREEDS OF DAIRY CATTLE

Top: Dutch belted; Jersey. Middle: Devon; Holstein-Friesian. Bottom: Ayrshire; Guernsey.

which are harmless in themselves, as most of them are, bring about changes in the milk during the processes of their growth. Then, too, there is always the possibility that the germs which carry infectious diseases, as well as harmless bacteria, may find their way into the milk. It is of the greatest importance, therefore, to have the milk that is delivered to our doors and sold in our markets as free from these bacteria as possible. To keep the milk clean is the first problem of every dairyman, and to make sure that he does this, state and city boards of health keep the public milk supply under close inspection.

Clean and safe milk can be produced only from clean, healthy cows in clean and sanitary dairies. In a modern, well-kept dairy the cows are housed in large, airy, well-ventilated buildings, which, together with all the other buildings where the milk is handled, are kept scrupulously clean. The cows are examined regularly by veterinaries, and are kept as clean and well-



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A PASTEURIZING MACHINE

Showing the large tank in which the milk is heated, and (at the right) the automatic recording thermometer.

groomed as famous race horses. The men who handle the milk must be immaculately clean, and all utensils must be sterilized.

As soon as the milk is drawn, either by hand or by electrical milking machines, as in the larger dairies, it is removed to a clean, dry room and strained through a metal gauze and a flannel cloth or layer of cotton. It is then cooled quickly to a point under 50° F., for at a higher temperature bacteria multiply very rapidly and there is greater danger of spoilage.

PASTEURIZED MILK

It has been found that heat kills the disease germs. So in many cities the law requires that milk be heated, or "pasteurized," and sealed in bottles before it is sold. Pasteurized milk is not boiled, for that would make it more difficult to digest and change its flavor, but is heated to a temperature of from 142° to 145° F. and kept at that point for half an hour. Then it is cooled rapidly. This process does not make poor milk good; it does not remove any dirt that might be present in the milk and it does not prevent bacteria which get in after the bottle is opened, from doing damage; but it does destroy the dangerous bacteria, and is very important in preventing the spread of disease by milk. The pasteurization process may be carried out before or after the milk is bottled.

CERTIFIED MILK

Certified milk is pure, fresh milk to which nothing has been added and from which nothing has been taken away. Unlike pasteurized milk, it has not been heated, but has been kept unusually free from bacteria by even greater than ordinary care in its handling. The standard established by law allows it to have only ten thousand bacteria per cubic centimeter. This makes it the best grade of milk obtainable. Because of the greater cost of producing it, the price is higher.

THE GRADING OF MILK

In order that the public may know the quality of the milk which is being sold, milk examining boards have set up standards. They base their tests on the number of bacteria present in a cubic centimeter, which is about the amount of one fourth of a teaspoonful, or sixteen drops. Every person who produces milk is required by law to have it analyzed at frequent intervals. If there are 30,000 to 50,000 bacteria per cubic centimeter present, the milk is ranked as Grade A. A count of 50,000 to 100,000 puts it in the Grade B class. In some places, a Grade C, which may contain even more bacteria, is allowed to be sold, but such milk is generally considered unsafe except for use in cooking.

EVAPORATED AND CONDENSED MILK

Since fresh milk spoils so easily, you can readily imagine how difficult it might be to obtain it in parts of the world where dairying is impossible and where the dairy centers are too far away to contribute a supply. Fortunately, it has been found possible to preserve milk by canning it, so that it can be shipped to all parts of the world.

The first step in canning milk is to get rid of part of the water, for it would be wasteful to pay to ship water, which is available everywhere, from one place to another. The milk is put into

Courtesy of H. P. Hood & Sons

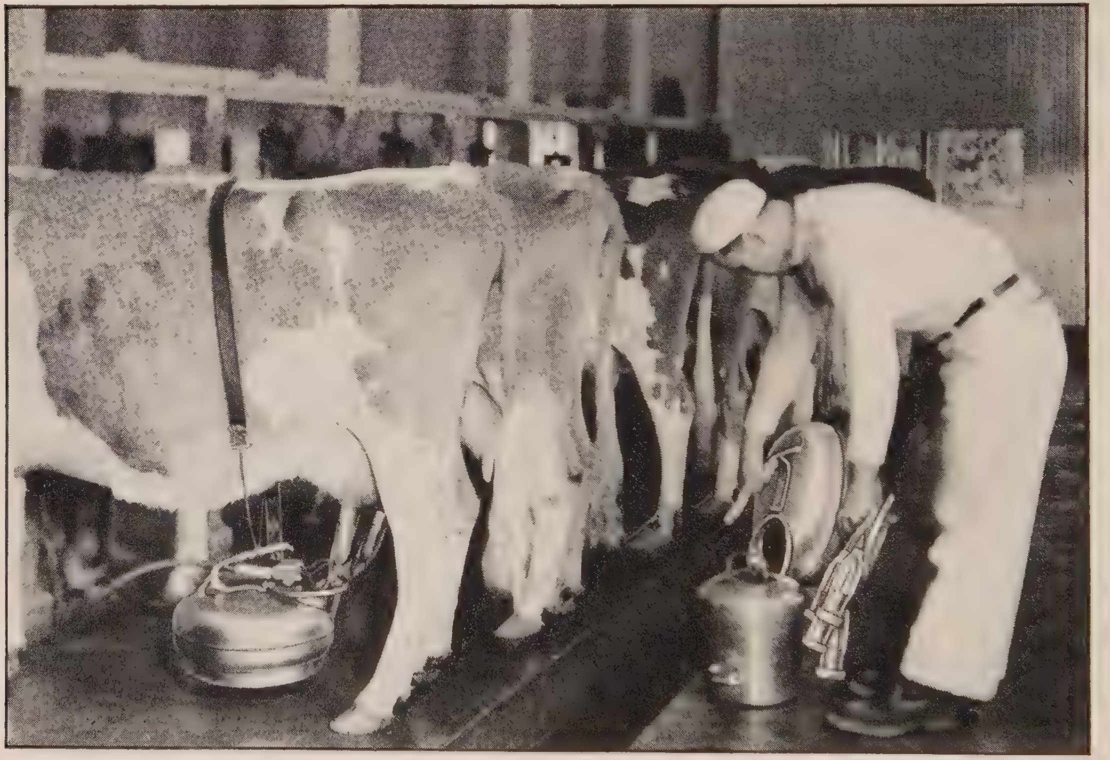
A COW BARN ON A CERTIFIED-MILK FARM

huge pans holding as much as ten tons and heated in a vacuum at 138° F. until about half the water has been evaporated. Then, in order to prevent the cream from rising to the top, as it ordinarily does, the milk is "homogenized" by being forced through an incredibly small passage which breaks up each tiny fat globule into hundreds of smaller ones which can never come together again and form cream. The milk is now ready to be sealed in cans of convenient size for household use and heated to a temperature high enough to kill any bacteria that may be present. This is what we know as "evaporated" milk. When an equal quantity of water is added to replace that which has been removed, it is equal in composition and fuel value to the original milk. The only change in nutritive value lies in the destruction which has been brought about in vitamin C; but since this is also destroyed by pasteurization, and is, at best, not present in milk in very large quantities, it is fair to say that evaporated milk is in all ways equal to fresh. It is always safe and can be kept indefinitely in the sealed cans. After it has been exposed to the air, it should be handled like fresh milk. Because the fat globules have been broken up, evaporated milk is even more easily digested than fresh milk, which makes it important in infant feeding. And because it can be kept indefinitely it is valuable to sailors, explorers and all who make long trips away from sources of fresh milk.

Condensed milk is prepared by a method similar to that used for evaporated milk, but before evaporation, sugar is added. When the first experiments in canning milk were made, the sugar was found necessary to improve the keeping qualities. Now, with improved methods, it is no longer essential, but the sweetened product proves useful and is made in large quantities.

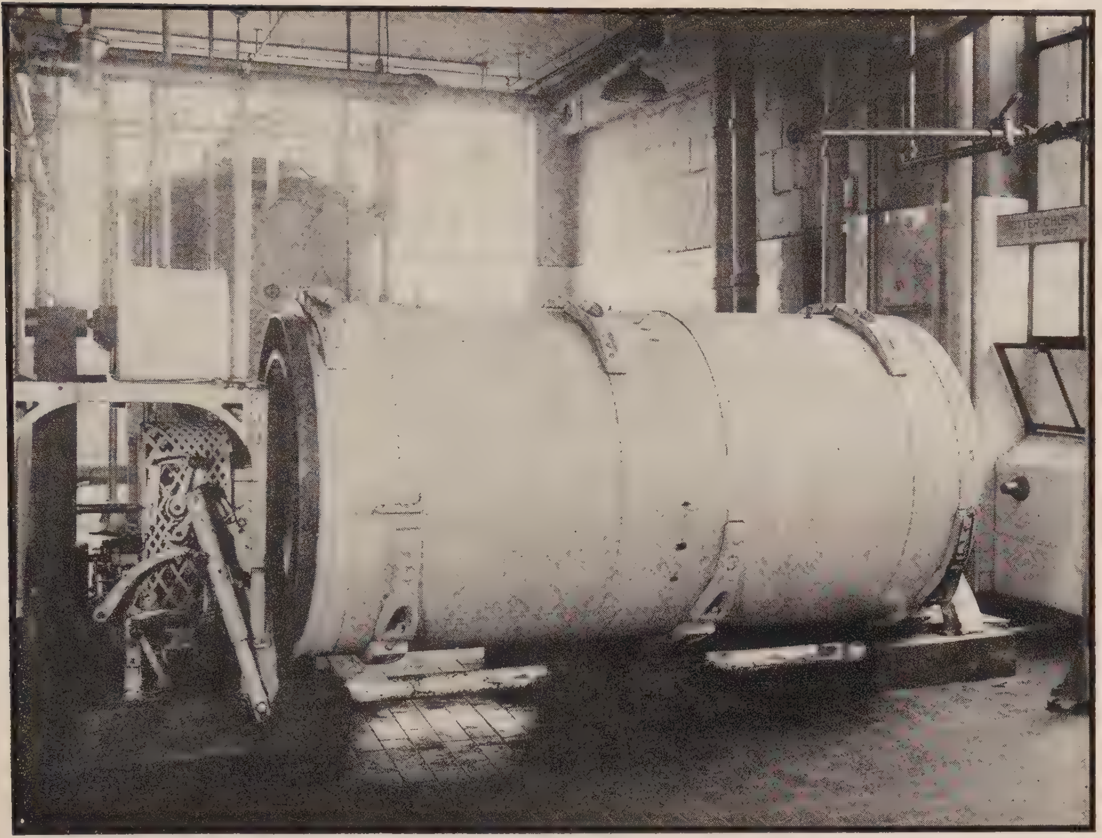
DRY OR POWDERED MILK

The most recently developed method of preserving milk is by drying it. This process



Courtesy of Babson Bros.

MILKING BY MACHINE AT AN UP-TO-DATE DAIRY FARM



Courtesy of H. P. Hood & Sons

A MODERN TYPE OF BUTTER CHURN

The capacity of this churn is a thousand pounds

consists of removing practically all of the 87 per cent of water which milk contains and reducing the solids that remain to a powdered form. The first step is to drive off some of the water by heat as for evaporated milk. Then the milk is either sprayed into a heated chamber where the moisture evaporates and rises, and the powder collects at the bottom, or poured upon revolving steel drums heated to such a high temperature that the water immediately evaporates, leaving a dry powder which is then scraped off. Both skimmed milk and whole milk are dried in this way, and are packed in such a manner that they will keep indefinitely. Of course, this form of milk is very easy to ship, and it is a simple matter to "reconstitute" it; that is, to make it like fresh milk again by adding the proper amount of water and mixing thoroughly to make a smoothly blended liquid.

IRRADIATED MILK

Pure, clean, rich milk, the basic food of children, is the most nearly perfect of all foods. However, scientists have recently discovered that the calcium (lime) and phosphorus in milk can function properly in the building of strong bones and teeth only in the presence of Vitamin D.

They have also found that by a process known as "irradiation" they can add Vitamin D to milk and other foods. Dr. Alfred Hess, one of the discoverers of this process, has said: "Irradiated milk seems to be the most desirable way of preventing rickets on a community scale. Only 20 to 24 ounces (2½ to 3 glasses) daily are needed to assure this protection."

In the process of irradiation, as the milk flows in a thin film over clean polished surfaces, the ultra-violet rays from a sun lamp increase the Vitamin D content in milk just as the ultra-violet rays coming from the sun increase Vitamin D in the body, when it is exposed to sunshine. Irradiated milk has lost nothing in flavor but has gained the protective value of Vitamin D.

THE MAKING OF BUTTER

It was quite by accident, according to tradition, that butter was discovered. Thousands of years ago an Aryan horseman galloped across a plain in Asia, carrying with him his goatskin bag filled with sour milk. The day was hot and the journey rough, and when he stopped to rest and take refreshment he was amazed to find a golden-yellow substance in the bag. He tasted it and pronounced it good, and told his friends about his strange experience. Soon the whole tribe was making butter by hanging up bags of sour milk and shaking them or beating them with sticks. The Hindoos learned the secret of butter making from the Aryans, and it was soon passed along to the other peoples of the earth. Although this ancient method of making butter by shaking milk in a bag is still used in some parts of the world, a primitive type of churn was one of the earliest household devices. Then butter was usually made in the farm home from cream skimmed from milk which had been allowed to stand in crocks in the cellar or milk house.

However, with the invention of the cream separator by DeLaval, the Babcock butterfat test which provides accurate checks on the richness of cream, pasteurization and modern sanitation, butter making has been largely removed from the farm and taken over by commercial creameries.

Huge machines do the churning, which is a process of agitating or shaking the cream until the fat globules unite into granules. The remaining liquid, buttermilk, is then drained off, and the granules are washed in pure cold water, drained, salted, and worked together into the smooth, solid form we know so well. In one recent year the United States produced nearly 1,700 million pounds of creamery butter valued at more than 400 million dollars.

Commercially made butter proves to be a more uniform and satisfactory product than the home-made, because facilities are more adequate, and conditions can be more carefully controlled.

BUTTER SUBSTITUTES

Butter substitutes, made from animal fats, oils of nuts, cotton seed and other vegetable products, are called margarines. Margarine of good grade is as high in fuel value as butter but does not furnish as many vitamins.

THE ICE CREAM INDUSTRY

Ice cream, which has become America's favorite dessert, probably originated in France or Italy. It was introduced into early colonial society. History records the purchase of an ice cream freezer by George Washington for use at Mount Vernon. Dolly Madison added to her popularity by being the first "First Lady" to serve ice cream at a White House function.

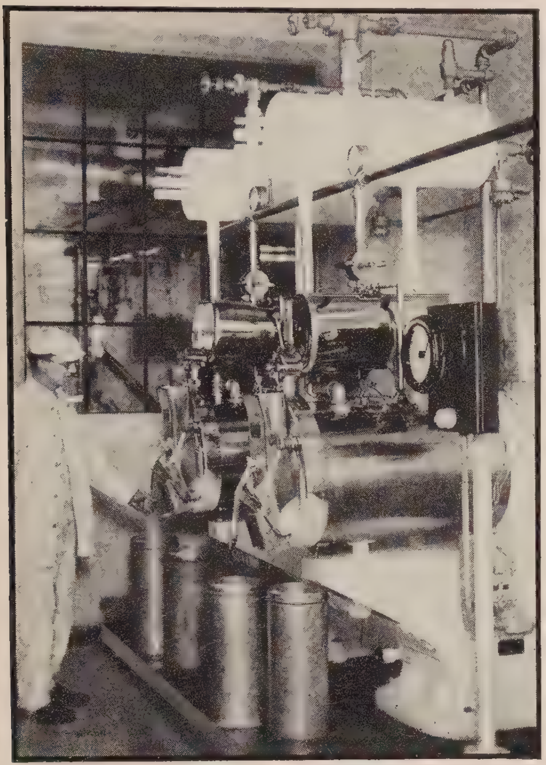
In the United States a large amount of milk is consumed in the form of ice cream. It is no longer considered as a "treat," but as a healthful article of food. It provides a rich source of phosphorus, calcium and growth-promoting vitamins. It is said that "ice cream makes every meal a banquet of health."

Ice cream furnishes a growing market for fruits and nuts. The ice cream industry uses more strawberries and peaches than any other except canning. The South depends upon ice cream for its largest market for pecans.

Like milk, ice cream is a perishable food and requires the strictest sanitary regulations. Federal and state laws govern its manufacture and distribution. In the modern ice cream plant, a highly trained staff checks the ingredients for quality and purity and controls the mixing, pasteurizing and freezing.

There are hundreds of different recipes and formulas for making ice cream; but they all consist essentially of milk, cream, sugar and sometimes eggs. To these, flavors are added as vanilla, chocolate, fruits or nuts. Usually a small amount of edible gelatin is used to prevent crystalization.

Only the best grades of milk and cream must be used to produce the best ice cream. First, the "mix" is prepared by placing milk and cream in the correct proportions in a mechanical mixer or other container, and adding a "stabilizer," which is often gelatine or gum tragacanth, to give body and smoothness. This mixture, like evaporated milk, is processed to break up the fat globules; then sugar and flavoring are added; and the whole pasteurized to reduce the number of bacteria. Freezing is carefully controlled so that the cream will be mellow and velvety. When it comes from the freezers, it is in a semi-solid state. It is then hardened in special receptacles in refrigerated rooms, and later cut, molded, and packed for shipment.



Courtesy of Food Industries

A PAIR OF COMMERCIAL ICE-CREAM FREEZERS

The modern method of packing ice cream for home use and train shipment is by the use of "dry ice," or "carbonic acid snow." This frozen carbon dioxide, surrounding the ice-cream can, evaporates into the air as a gas instead of melting to a liquid, as does true ice. In this process it absorbs heat from the ice cream and thus keeps it cold.

CHEESE, ANOTHER DAIRY PRODUCT

Still another product of milk is cheese, made from the solid constituents, brought together by a special process and separated from the whey or watery part. The story of how cheese first happened to be made reminds us of the discovery of butter. It was an Aryan herdsman this time who, thousands of years ago, set out to spend the day caring for his flock. He took with him, in a bag made from the stomach of a sheep his lunch of milk. When he sat down under a shady tree at noon and started to drink the milk, he found that something was wrong. There was a watery-looking liquid in the bag, like nothing he had ever tasted before. It was not unpleasant. So he proceeded to drink it. Then out of curiosity he ripped open the bag to try to discover what had happened to the white part of the milk. He found a mass of lumpy, yellowish, semi-solid material which tasted very good to him.

Now what was it that caused the milk to turn to cheese, for that was what had happened? It was the dried digestive juices of the sheep, left on the walls of the bag. This juice contains a substance, to-day called "rennet," which acts upon the casein, the protein substance of milk. Casein, on contact with rennet, is coagulated or thickened; that is, the casein particles draw together, catching other food particles out of the liquid, and forming a soft, partially solid mass. This is the cheese curd, which is the basis of all the four hundred varieties of cheese which have been developed. In order to make the curd more convenient to handle and more appetizing to eat and to improve its keeping qualities, the water is pressed out, leaving a firmer curd. Cottage cheese which is made at home is simply cheese curd at this stage.

But most of the cheese which we buy has been ripened. It has been worked into a smooth mass and left to age and develop flavor. The flavor and texture of cheese depend largely on what takes place during the ripening process. Bacteria and molds, tiny vegetable organisms, feed on cheese, just as they do on milk, and different kinds struggle with one another for first place. The one that wins out gives the particular character to the cheese that differentiates it from other varieties. At first, variations just

Courtesy of Kraft-Phenix Cheese Corporation

A CHEESE VAT SHOWING MATTED CURD

happened, but as the process of cheese making has been studied, cheese makers have learned how to cultivate and introduce into the curd just the kinds of bacteria and molds they want.

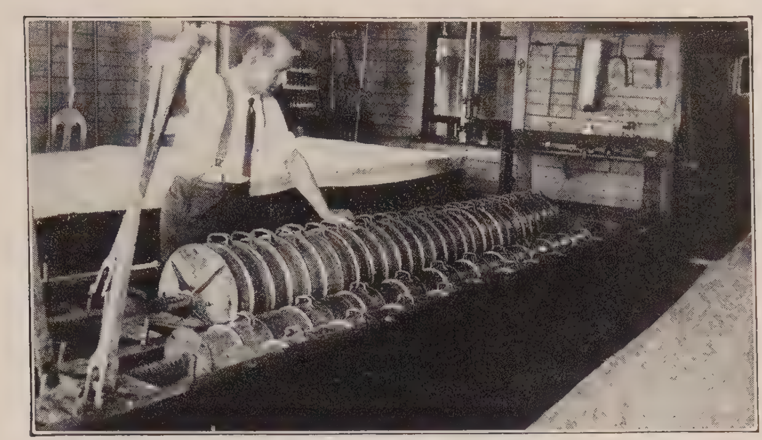
There is an interesting story about the discovery of the kind of cheese called Roquefort. A shepherd one day left his lunch of barley bread and cheese in a cave near the town of Roquefort in France, intending to return for it later. A storm came up, and in looking after his flock he forgot about the lunch. Two weeks later he passed the cave and happened to think of the food he had left. He investigated and found that the bread had spoiled and the cheese was riddled with a curious green mold. He tasted it wonderingly and found it delicious. His curiosity was aroused, and to see if the same thing would happen again he left the fresh cheese and another piece of bread which he had with him. When he came back after another two weeks, there was more of the green-mottled cheese that he had found so appetizing. That was eight hundred years ago, and to this day cheese is made in a similar fashion in this same cave and others near it. The flavor is due to an unusual mold that develops from bread in the peculiar atmosphere of these caves.

The early settlers of the United States brought the art of cheese making with them and it flourished in Colonial kitchens. It was not until 1851 that cheese making became a factory industry. At that time a factory was opened in Oneida County, New York. The Cheddar method, developed in England, was used, and the Cheddar type is still the most common of American cheeses. It is a firm, solid cheese, yellow in color.

With increasing production, the industry spread westward, and Wisconsin soon became the leading cheese-making state. To-day, in its 2800 factories, it produces more than 70 per cent of all the cheese manufactured in this country. The Pacific coast states and also Idaho and Colorado produce large quantities.

HOW CHEESE IS MADE IN THE UNITED STATES

In a modern cheese factory, milk is received every morning from the surrounding farms. After being weighed and analyzed it goes into vats which hold from 3000 to 4000 quarts. The milk is then heated to 86° F., a lactic acid "starter," or culture, mixed with it, and rennet added. If a yellow cheese is being made, a vegetable coloring is used. The milk is then left undisturbed for 30 to 40 minutes, or until the curd is quite firm. At this point in the procedure the curd is cut, first vertically from one end of the vat to the other, and then crosswise, to allow the whey to escape. The whole mass is stirred, and heated gently until the proper body and acidity are produced, and the whey is drained off. Milling, or cheddaring, the curd comes next. It consists of a repeated piling up of large pieces of the curd to expel any whey that is left, then putting this matted cheese through a milling machine which breaks it up into small pieces. Salt is added, the curd cooled



Courtesy of Kraft-Phenix Cheese Corporation

PRESSING CHEESE CURD INTO DAISY AND LONG HORN MOLDS

to 80°, then packed in hoops, or forms, and pressed for a number of hours. For many years the large, round cheese was the only one known, but now a variety of shapes is used. After being taken from the hoops, the cheese goes to the curing rooms to ripen, and before shipment it is paraffined.

Pasteurized cheese is a product which has been developed during the last few years, and meets the present-day demand for standardization. The process consists of blending a number of different lots of ordinary American cheese, which may vary somewhat in flavor, fat content, and so on, to give a product conforming to definite standards of composition. The selected cheeses are shredded by a special machine, mixed together, and then pasteurized to reduce the number of bacteria and thus improve the keeping qualities. While it is still in a soft state the cheese is pressed into boxes.

A still later development in blended cheese is one in which the mineral materials of the milk, which are ordinarily lost in the whey, are, by a special process, returned to the cheese. This type of cheese is marketed in small, tinfoil-wrapped packages.

IMPORTED CHEESES

Swiss, or Emmenthaler, cheese, which is one of the most popular of our imported cheeses, is a hard variety, characterized by large holes. These holes are formed by a gas which is generated during the ripening process. Stilton cheese comes from England, and, like Roquefort, is marbled with green mold. Gorganzola is an Italian cheese of the Roquefort type. Parmesan cheese from Italy is so hard that it will keep indefinitely, and is at its best when ripened over a period of three or four years. It is most familiar in grated form. Camembert cheese takes its name from a town in France where, it is said, it first came to the attention of Napoleon. It is a very soft cheese with a moldy rind. Many attempts have been made to produce Camembert cheese in this country, and recently a considerable degree of success has been attained. Limburger, named from the town of Limburg in Belgium where it was first marketed, is notorious for its strong odor. This characteristic is due to putrefactive fermentation brought about by the moist condition in which the cheese is kept during the period of ripening. Edam cheese is a hard, mild cheese from Holland. It is shaped in round molds and dipped in crimson or deep yellow dye, usually the former. Neufchâtel, of French origin, is similar to cream cheese. It, however, is made from whole or even skimmed milk, whereas cream cheese contains an extra proportion of cream. Both Neufchâtel and cream cheeses are unripened and do not have the keeping qualities of the ripened cheeses. Brie is a cheese originating in France and common in all parts of that country. It is now made extensively in the United States. Pineapple cheese, often thought to be imported, is a hard American cheese, dried and ripened in a close-mesh net.

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WHEAT THE LEADING NORTH AMERICAN INDUSTRY

The United States and Canada have the greatest wheat fields in the world

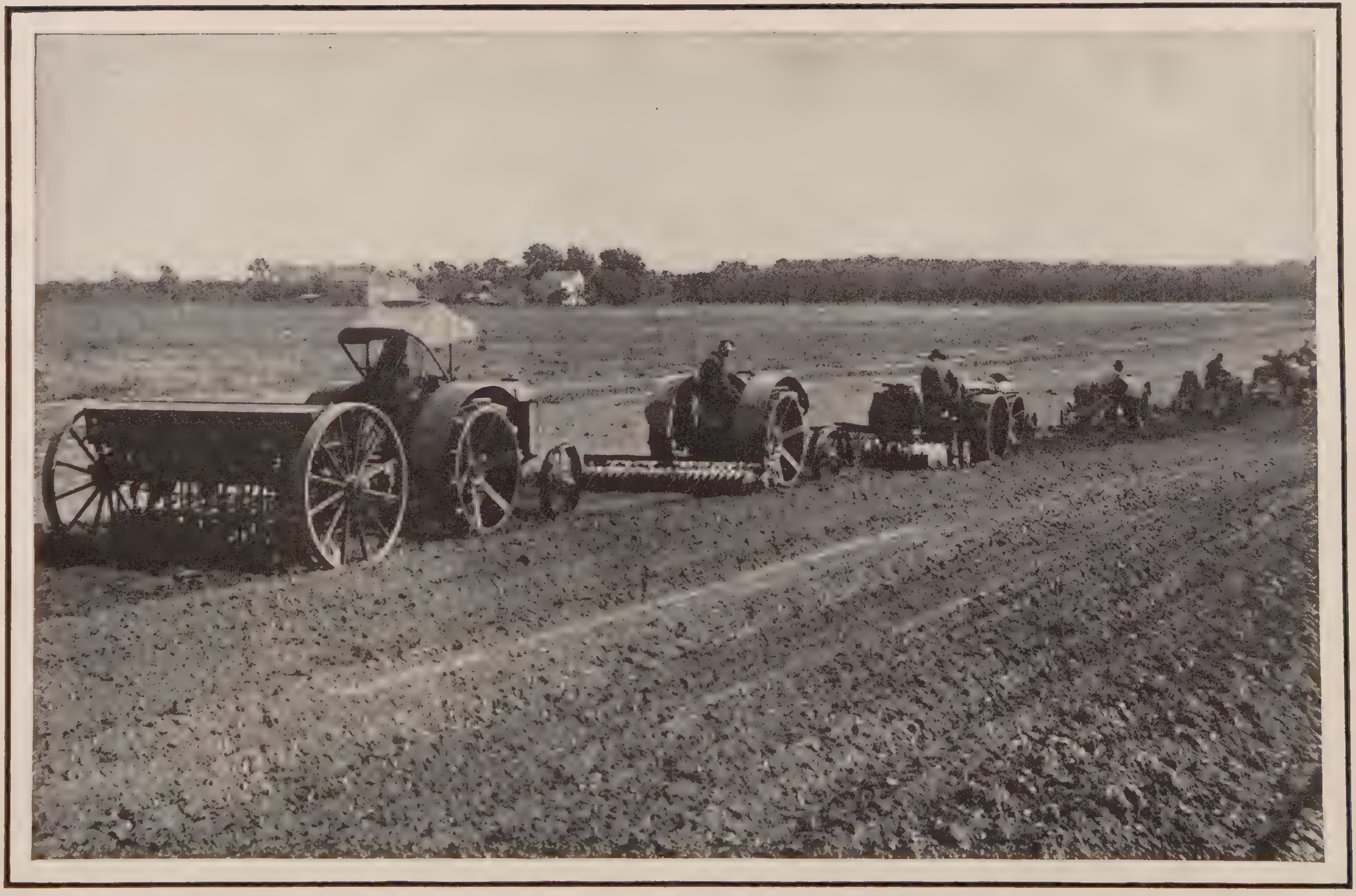
Courtesy of International Harvester Co.

OUR WEALTH IN CEREALS

MATCHING the wealth of the waters, from which men draw fish for their food, is the wealth of the boundless acres of open prairies where the grains of the earth grow in abundance. Food is one of the prime necessities of mankind. In the story of "Fisheries" we have described one of the simplest of food industries. Here we have animal food, abounding in the waters, and replenishing itself year after year with little or no cultivation. The fish are taken from the sea and dispatched quickly to the consuming public. Any processes which they undergo in preparation are chiefly to preserve them as they are, not to transform them into any more complicated product. In the story of the wheat fields we have a food industry depending on a plant instead of an animal product. This industry, too, has been pursued from prehistoric times; it, too, ministers to a basic human need. But here modern science and modern machinery have entered with a transforming hand. Wheat would be a valuable product under almost any conditions. It was valuable under the tillage of the early farmer who dug his land with a pointed stick, sowed his seed with a toss of his hand from the sack, covered it with a harrow, and then waited for the harvest, which he would reap with a sickle and thresh with a stick or flail. But if wheat was a precious product in those days, how much more precious is it now, when the yellow fields of a nation's wheat belt are watched as if they were so much fine gold, when the wheat crop of a country may spell its prosperity or financial depression until another harvest come, when wheat is an "international food" and the reports of its growth are the concern of governments and financiers? We shall do well to follow the story of this grain, which is the raw product of an industry toward which the eyes of all the world are turned.

WHEAT IS A CEREAL GRAIN

Away back in the dawn of history man discovered that the seeds of the wild grasses which grew at his door were good to eat. So the wise husbandman refrained from eating in a given year all the seeds that came from the plants, and gathered some to keep until the next season, when he could plant them and have more



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TRACTORS PREPARING THE SOIL FOR WHEAT PLANTING

Courtesy of International Harvester Co.

A COMBINED HARVESTER AND THRESHER

grasses and more seeds to eat. Year after year he tried out the different grasses, and found some, the wheat grasses, which suited well both his soil and his taste. So he cultivated them, and this was the first wheat field.

The wheat plant as we know it has never been found growing wild. In every land where it prospers the wheat grass has been carefully tended by man. In the early days there may have been only one kind of wheat, but that time is far back of the reach of human history. Different kinds of soil, of climate, and of care have tended to produce different kinds of wheat. In our own day new varieties are being hunted out in every quarter of the globe and crossed with those varieties which we know, so that better, stronger wheat plants may be developed, some for the wetter climates, others for the drier, some for the winter months, others for the spring.

THE WORLD'S WHEAT BELT

If you could see a globe with a map of the world spread on it and the wheat belts of the world were shaded into a golden yellow, you would notice that the yellow areas were chiefly in the temperate latitudes, where the climate was moderate and the rainfall considerable. Wheat does not thrive in very hot or very cold regions. After the seed has been dropped into the fertile soil, the ground should be cool and moist. In such a soil the seed will germinate quickly and send out many stalks. When the grain is ripening, the weather should be warm and dry, so that the plants may mature quickly and fully.

Such conditions as these are most likely to be found in the temperate latitudes, on the prairies of the Middle West and the plains of Canada, on the steppes of Russia and the pampas of Argentina, in North Africa and Australia, above and below the equator in any region where the conditions of climate resemble for some period of the year those of our own temperate zone. Yet wheat is not limited to a single season. If the traveler will shape his course with this in mind, says one agricultural writer, he need not fail to find a ripened wheat field in any month of the year. "He may start in November in South Africa, proceed in December and January to Australia, cross the sea to India in February and March, and go on to Egypt in March or April. In May he can visit Algiers, in June Italy and Spain, in July and August central Europe, and in September and October he will discover the harvest

Ewing Galloway

GRAIN ELEVATOR AND GRAIN SHIPS, BUFFALO

in Scotland, Scandinavia, and Finland. Even in North America the harvest lasts from April, in Mexico, to September in Western Canada."

In the southern regions of the wheat belt, where the winters are not extreme, wheat may be planted in the fall sufficiently early to get a start before the winter season begins. Then it will be hardy enough to survive the winter and will begin to grow again in the early spring as soon as the frost has left the ground. This gives the earliest crop of our own continent, maturing in the late spring, and is called "winter wheat." Farther north the wheat will be planted as soon as the snow is gone, and will sprout and develop fast on the heels of the more southerly crop of winter wheat, following it with an interval of four or six weeks. So the planting and the harvesting of our great wheat fields goes on month after month as the seasons swing around. In the spring and summer months the transcontinental traveler will ride day after day across the great flat plains of the United States or Canada seeing only the acres of grain stretching away into the distance like the waters of the ocean. A map may indicate a wheat belt encircling the globe, but of the beauty and of the seeming infinity of these waving fields of grain, only one who has lived among them, or watched them day after day as they flowed past a swift-moving train that still seemed never to pass beyond them, can have any real conception. Not in the narrow confines of Wall Street but in the crops of the rich lands of the farmer, as they are tended by an army of sturdy workers, lies the real wealth of the United States.

The so-called "interior wheat belt" stretches across North Dakota, Kansas, Minnesota, Nebraska, South Dakota, Indiana, Illinois, Ohio, Oklahoma, and Missouri, and is matched by the wheat-producing states of the Pacific Coast, — California, Oregon, and Washington, — and the northern fields of Manitoba, Saskatchewan, and Alberta. Within these regions but in a narrower area lies the "corn belt," producing an almost equally important and even more abundant crop. Corn or maize is native to our country, and is one of the chief and most interesting of our American products. It cannot endure frost, and is therefore limited in its range to regions with a longer temperate climate, such as the prairie region of the Central States. Corn is the most valuable as well as the largest of our crops.

WHEAT AS AN AMERICAN INDUSTRY

Both wheat and corn rank high as American industries. While we raise more corn than wheat, still wheat is usually reckoned the leading industry because so much of a corn crop is turned back as fodder for the raising of live stock, while wheat is perhaps man's most important food.

The story of the machinery used in the wheat fields has been told in an earlier part of this volume in the account of inventions which have been epoch-making in our national and international life. The soil is turned up by huge gang plows; the scattering of seed by hand gave place long ago to a distribution by modern machine seeders which may leave a seeded path a dozen feet or so wide; the huge harvesting machine, which cuts a swathe twenty, thirty, forty, or even fifty feet wide, may very likely be a thresher and a binder as well, so that the standing wheat in front of the machine comes out behind it in sacks of grain practically ready for transportation. There are small farms as well as large in our wheat states. There must be men to run these mammoth machines as well as men to follow the simpler methods of the smaller wheat grower. So there goes up in the season the cry for men and more men on the wheat fields, and an immense army of workers responds — ready to go from district to district, as the call comes, to satisfy the demands of the farmer for help in the harvesting of this quick and extremely important crop.

ONE OF THE ELEVATORS OF THE WASHBURN-CROSBY CO.

GRAIN ELEVATORS

When the crop is harvested, there comes the next pressing demand. The wheat must be stored, first locally, and then in the great distributing centers, where it must be held until it can be shipped to its destinations for manufacturing or export. For this purpose there has been developed a special kind of building, known as a "grain elevator," equipped for receiving, storing, and discharging grain. These warehouses are located throughout the wheat areas, and are built in great numbers near the railway lines and wharves of the great distributing centers. They contain many floors over which grain may be spread to dry, or bins in which it is packed away from the air. Some grains, among them wheat, are better sealed and are therefore put in closed bins which open only at the bottom.

It has required no little thought to perfect the machinery used in transporting grain from ships and trains to the floors and bins of these warehouses. The unloading is generally done by elevators placed at intervals along a pier. The

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A GREEK THRESHING SCENE

first one has a set of buckets which are let down into the hold of the vessel, where they scoop up the grain. These buckets are arranged on an endless band which passes over rollers at the top and bottom, and which hoists the grain forty or fifty feet. From seventy-five to one hundred and fifty tons can be carried from the ship's hold in an hour; it depends on the size of the buckets. After these buckets reach the top of the elevator they are emptied into a spout which carries the grain to a bin; here a second elevator lifts the grain still higher, and from this point it flows down of itself into weighing hoppers. As soon as two tons collect in these hoppers they are automatically emptied into still other bins and the grain goes then to the receiving elevators of the warehouse. Spouts afterward transfer it from these receiving elevators to the storage bins awaiting it. Here it remains until needed for the market, when it is either taken out and aired and then sent back to the bins, or is shot down shafts into wagons or vessels.

THE PNEUMATIC TUBE FOR UNLOADING

One objection to the bucket elevator in unloading ships is that unless the grain is directly beneath the hatchway it is very difficult to reach it. Therefore in recent years a flexible pneumatic tube has been invented which by air pressure sucks up the grain. This tube can be carried to any part of the ship. The moment a vessel docks this tube may be plunged into the grain and set to work. It is less awkward than the buckets and often accomplishes the task of unloading more speedily.

The grain-elevator business is a great one, and employs many thousands of men. Chicago, Buffalo, Duluth, and Omaha are among the large grain-shipping points.

FLOUR

THE process of turning the raw wheat into the flour of which we make our bread is called "milling," and it is one of the greatest of American industries. In very ancient times saddle stones were used for grinding wheat into flour, the wheat being placed in a hollow stone and rubbed with a rounded stone rocked backward and forward. Half-civilized people of to-day still use them. About the beginning of the Christian era stone crushers, called "querns," were used. Many years afterward specially hewn millstones, moved by slaves or oxen, were introduced. Later, water wheels and windmills were used as motive power for the millstones, and lastly steam.

What a contrast between those primitive flour mills and the wonderful mills of to-day! In these great buildings the wheat is ground between many sets of steel rollers, passing automatically from one set to another.

As late as 1870, however, the flour of America was still being ground between millstones, and it was a much inferior grade of flour to that produced to-day. The roller process was introduced from Hungary in 1870, and revolutionized the American milling industry. By the old process of grinding between millstones, it was hard to separate the "middlings" of the wheat kernel from the bran, although they are rich in the gluten that gives wheat flour its chief value in bread making; hence, the middlings were wasted. By the roller process they are saved

Courtesy, General Mills, Inc.

ROLLER PROCESS FLOUR GRINDERS

Courtesy, General Mills, Inc.

PACKING FLOUR IN FIVE POUND BAGS

and produce the high-grade patent or white flour of to-day, with greatly enlarged profits to the manufacturers.

The middlings are that portion only of the kernel between the bran covering and the central body, or germ. When the entire wheat kernel is ground into a meal it is called "graham" flour. When a portion of the bran is removed, but the germ and fine bran are retained, the product is called "whole wheat" flour.

The bran which is removed in milling is used in various ways. Much of it goes into feed for cattle and horses; some of it is specially prepared in cereal form for human consumption. It is valuable for its laxative properties.

Bread made from graham or whole wheat flour is a more complete food than that in which white flour alone is used, for in the outer coats and the germ are some of the minerals and vitamins essential to life. With the varied diet, which most Americans have, however, there is no necessity for giving up white bread entirely in favor of the whole-grain varieties. White bread is an excellent food, and if you prefer to eat it most of the time, simply remember to include unusually generous amounts of fruits and vegetables to furnish the constituents which it lacks.

Whole grain flours, because of the oil content of the germ, quickly develop a "rancid," or stale, flavor. For this reason, and because of the lower gluten content, they are less popular with American bakers and housewives than is the highly refined white flour.

HARVEST TIME

A "PIG CLUB" INSPECTING ITS PROPERTY

Corn is one of the chief foods of the animals which supply our meat.

OTHER GRAINS IN ABUNDANCE

CORN IS KING

YOU have probably heard or read somewhere that corn is king and have wondered why such a thing should be said. It means that corn is the greatest crop that this country produces. Wheat is more important as an industry because thousands of people are employed in milling it and making it into flour; whereas the greater part of each year's corn crop is fed to the cattle and other animals in the district where it is raised. However, more corn is raised than any other grain; in good years as high as three billion bushels. If all this corn were shipped to market it would be enough to fill a train that would reach four-fifths of the way around the earth at the equator.

Corn is a native American product, used by the Indians centuries before Columbus, and introduced by them to the first settlers. It was at first called Indian corn, or maize, and many nations still use that name to differentiate it from the "corn" which is the general name given to whatever grain is raised in greatest abundance. Seed was soon carried to other countries, and now corn is an important crop in Italy, India, Egypt, and other countries of the Old World, but the United States still produces far more than any other country.

To grow luxuriantly, corn needs a deep soil, abundant rainfall, and hot summer nights. Such conditions exist in the Mississippi Valley, where our great corn belt lies, but the grain can be raised in every state in the Union, and there is hardly a farm in the country but has its corn field to supply food for the livestock. Much of the crop produced in the corn belt is fed there, but some is shipped to other parts of the country which are unable to raise enough to meet their needs.

Each year the best of the corn is saved for seed and by selecting this seed carefully, the yield and quality has been greatly improved.

Not only is the ripe grain consumed by livestock and chopped or shredded stalks used as "dry fodder," but many acres of corn are grown and harvested for "ensilage." The entire plant, just before the ears are fully ripe, is cut fine and stored in silos, those tall round buildings which are seen on almost every farm. The corn ferments slightly as it stands in the silos and makes a fine succulent food for use in the winter when there is no green grass.

Of the total amount of corn produced less than ten per cent reaches the markets, to become an article of exchange, or "cash corn" as it is called.

Approximately a third of the corn which is marketed is purchased by the industries concerned with the manufacture of corn products. A kernel of corn, like a grain of wheat, is made up of endosperm, germ, and hull. Each of these parts has its use. From the endosperm, starches, sugars, and gums are produced. From the germ are manufactured oils, both for food and for industrial uses, and also corn-germ meal, which is valuable as feed for livestock. The hull, together with the fibrous material and gluten from the endosperm, goes into feed for animals.

Some of the corn is prepared as cereal or flour. With the outer coatings removed and the kernels broken or coarsely crushed, hominy or "samp," which is often used in place of a starchy vegetable, is produced. A somewhat finer grind is known as the hominy grits popular as a cereal. Corn meal is a still finer grind and corn flour, the finest of all.

It is true that corn meal is in much less common use in our kitchens than wheat flour, but more corn appears on our tables than perhaps we realize. Corn bread or pone is particularly popular in the South and "Johnny cake" in the New England states. We often use breakfast cereals of corn in many forms, from whole hominy to crisp corn flakes. Then we have cornstarch, a thickening agent for cooking, corn syrups, and cooking and salad oils. In India, corn is raised for the ripe grain and the unripe cobs are also used as a green vegetable. In South Africa, "mealies," prepared from corn, is a staple article of food of the natives; the Mexicans could not do without their "tortillas" and "tamales;" Italians eat much "polenta;" the Irish are fond of "stirabout," a mixture of oatmeal and corn meal cooked in water or whey and milk.

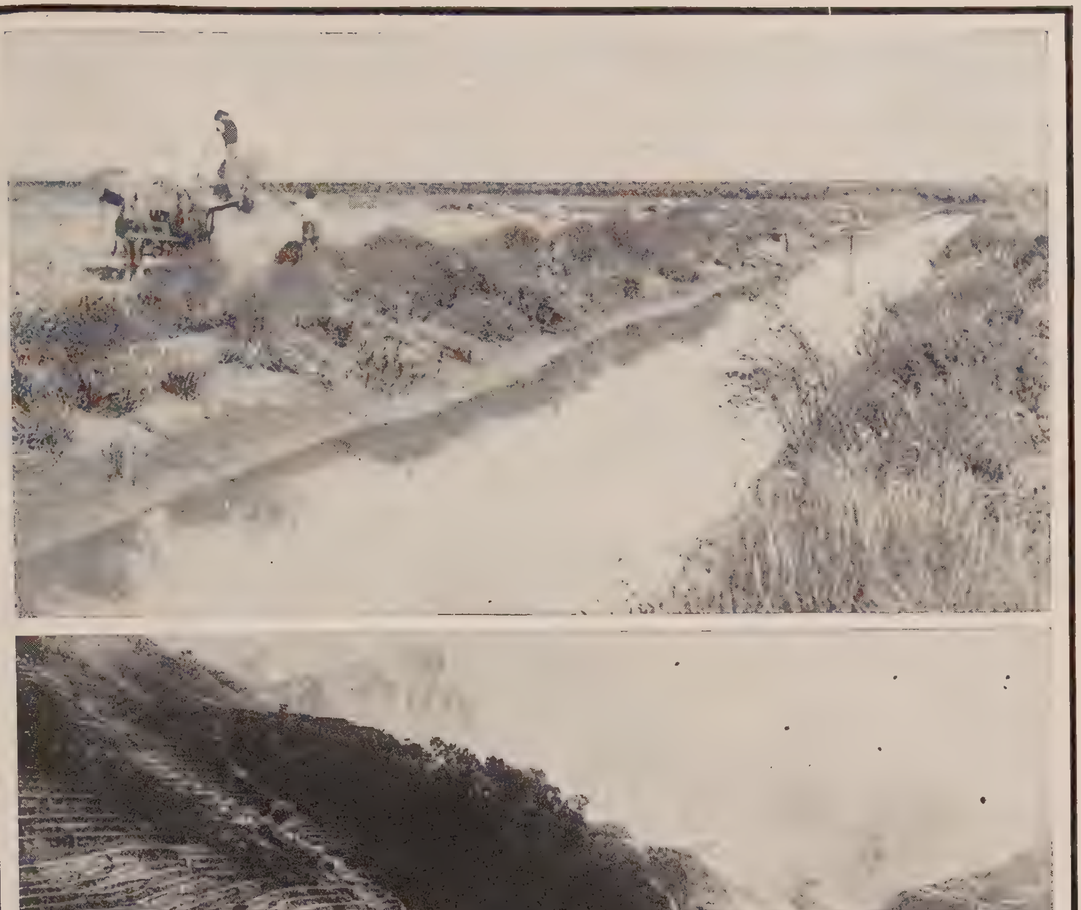
Sweet corn is a garden crop, one of the most popular vegetables we have. The canning of corn forms an important industry in the northern United States, from the Atlantic coast to the Missouri River.

Popcorn is a peculiar variety of maize which explodes when subjected to intense heat, turning almost entirely inside out. We use it sometimes as a cereal, but more often as a confection.

RICE

Rice does not seem nearly so important to us as wheat and corn, but it is the principal food of over one-third of the population of the world and is the grain which is most extensively cultivated. When we study about it we realize that it is an important crop in our country, too, and more and more of it is being grown. It was first brought here in 1694 by a ship from Madagascar which was blown out of its course and landed at Charleston, South Carolina, for repairs. The captain gave a small parcel of rough rice to the governor of the colony, who used it for seed. The industry of rice growing developed rapidly in that state and in Georgia. Later it spread to Louisiana, Texas, and Arkansas, and more recently to California. These four states now produce almost all the rice grown in the United States and are developing into one of the world's greatest rice-growing centers. Our rice fields are highly productive, yielding crops of unusual quality as well as quantity, and our extensive use of machinery offsets the cheapness of labor in foreign countries, so that American rice is taking its place in international commerce.

The culture of rice differs from that of other grains in that the lands must be kept flooded during most of the lifetime of the plant. As soon as the rice plants are three or four inches



Keystone

THE CULTIVATION OF RICE

Above: A Texas rice field. Below: A Philippine hillside, converted into terraces which can be flooded for rice growing.

tall, the fields are covered with water, to a depth of from two to six inches, and kept constantly flooded until the rice has headed up. Then the water is drained off and the fields are left to dry for ten days or two weeks before the grain is harvested.

Rice is cut in exactly the same manner as wheat, and is threshed by a process which is similar also. Milling consists of removing the husks and outer bran coats, and polishing the grain between pigskin-covered cylinders. Much of the rice which is sold in bulk in the United States is coated with a preparation of glucose and talc. The finest qualities, however, are uncoated. Since we have been learning more about the nutritive substances contained in the outer coverings of grains, there is an increasing demand for natural, or brown, rice which has had only the husks removed.

RYE

Rye is a grain that grows best under the same conditions as wheat, but it is very hardy and can be raised in latitudes too cool, and in soil too poor, for wheat. It is the principal cereal of northern Russia, Scandinavia, and Germany. It is used in breads, but does not make the light, white bread that we like best. However, rye bread is in fairly wide demand at present, for it has been introduced to us by natives of foreign countries, and we have learned to like it.

OATS

Oats are widely cultivated in northern Europe and North America, and used as a food for men and horses. We know it best in the form of rolled oats or oatmeal, as we often call it. Rolled oats are prepared from the husked and sterilized grain put through heated rolls which flatten it out into flakes. Much of the oatmeal cereal which we buy has been partially cooked by steam, so that it needs only a few minutes preparation in the home kitchen. The oatmeal of the Scotch and Irish is made by grinding the grain, and long cooking is required to bring out its flavor and make it palatable. Only three per cent of the billion or more bushels of oats produced annually in this country is used as food for human beings. The rest is fed to livestock.

BARLEY

Barley is a grain which we use very little; yet it was perhaps the first grain crop of the human race, cultivated from remotest antiquity and grown in nearly every part of the world. Until the middle of the eighteenth century it continued to be the great food grain of Europe and has been only recently superseded by wheat and rye. It is even now used extensively, ground into a meal, in the coarse, dark breads of some of the European countries. During the World War barley flour was one of the substitutes with which we made bread and cake, but now it appears principally in pearled form in soups. Pearl barley is the whole grain with outer and inner husks removed.

BUCKWHEAT

Buckwheat is a cereal which we know best in pancakes, on cold winter mornings. It is a native of Siberia and was said to have been brought to Europe by the Crusaders. In this country it is raised in the largest quantities in New York and Pennsylvania.

MACARONI

Although we think of macaroni as a typically Italian food, history credits its invention to the Chinese and its introduction into Europe to the Germans. It is not, of course, a cereal in the true sense of the word, but it is such an important cereal product that it cannot be omitted from a discussion of the grain industries.

Macaroni is made from a special kind of hard wheat, called "durum," which contains a high percentage of gluten. This is ground into a meal known as "semolina," moistened with water, and mixed to a smooth paste. It then goes into the cylinder of a press and is forced out through holes in the bottom of the cylinder. The size and shape of the holes determine the form of the macaroni. A round hole with a steel pin in the center makes the familiar tubular shape. The finer spaghetti comes through a smaller round hole without the pin. Small fancy shapes are sliced off by rotating knives as the paste comes out of the press.

In Italy macaroni is dried out of doors, but in

Courtesy of Food Industries

THE PRESSROOM IN A MODERN MACARONI FACTORY

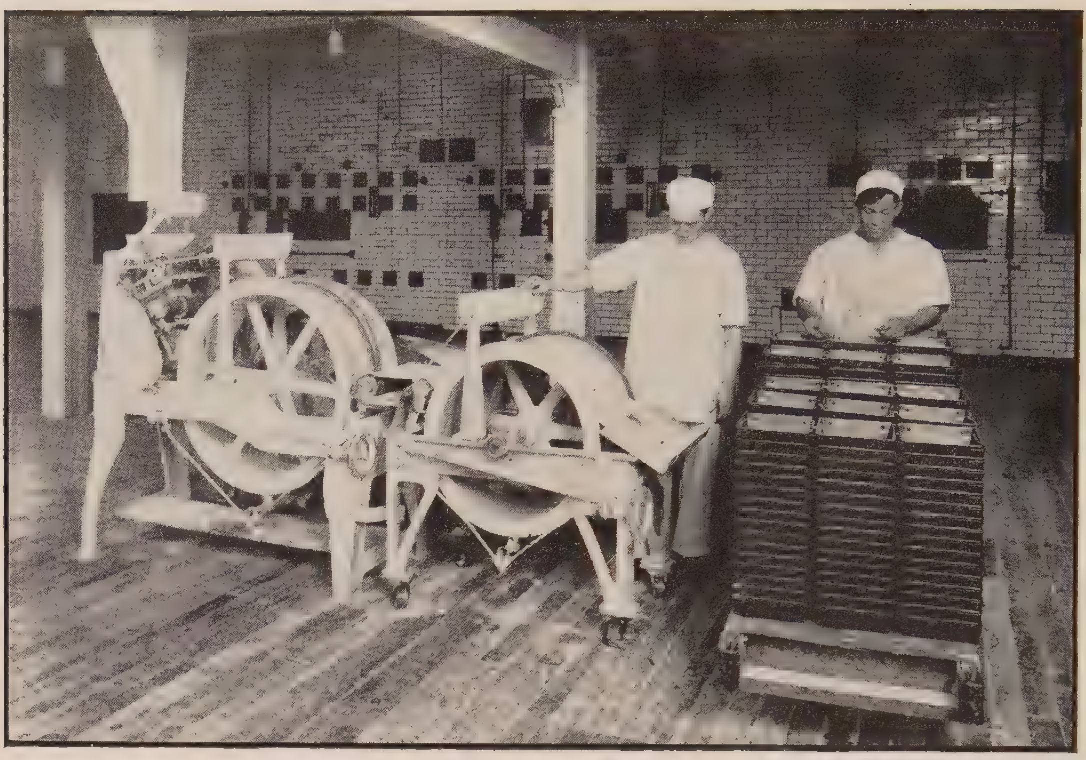
Showing how macaroni comes from the presses and is hung on racks ready to be taken to the drying room.

our modern factories a more efficient and sanitary method is provided by drying rooms in which temperature and moisture are controlled.

TAPIOCA

We are inclined to class tapioca as a cereal though it does not come from grain at all, but is made from a starch furnished by the root of a woody, tropical plant, the manioc or cassava. This plant grows in South America and the West Indies.

The starch, after being separated from the fibrous part of the root, is heated until the granules burst, forming small irregular masses. They are then baked to remove moisture. Pearl tapioca is made by forcing the moist mass through sieves. The quick-cooking variety which is most used at present has had further pre-cooking and drying, after which it is ground into granular form.



THE MACHINE IN WHICH BREAD IS SHAPED FOR THE TINS

COMMERCIAL BREAD MAKING

YEARS ago every housewife baked her bread, just as she carded her flax and spun her yarn. She had no other way to get it. Now in every city and almost every town there are professional bakers who bake from three hundred to ten thousand and one hundred thousand loaves a day.

THE FOOD VALUE OF BREAD

Good bread is an economical and valuable source of readily digestible food energy. One ordinary slice of white bread provides about 65 calories, or units of food energy. This is enough food energy to enable a man to walk a mile.

But bread is more than an energy food. It also contains valuable tissue-building proteins, derived from both the wheat and the added milk, and it has important minerals, such as phosphorus, calcium and iron, and small amounts of the growth-promoting vitamins A, B_1, and G. In the bread known as "fortified" bread additional quantities of vitamins, prepared chemically, have been added.

Scientists have estimated that, while bread and cereals represent only 17 per cent of the total food bill of this country, they furnish 40 per cent of the energy value, 25 per cent of the protein value and 18 per cent of the phosphorus value.

HOW IS THE BREAD MADE?

The modern large bakery is a spotlessly clean industrial kitchen, equipped with huge machinery and operated by technically trained experts. First the flour goes into large mixing machines where it is combined with measured amounts of other ingredients, such as milk, sugar, salt, yeast, malt and fat or shortening, to form a dough. The yeast promotes fermentation and this in turn releases countless little bubbles of carbon dioxide gas which cause the dough to rise.

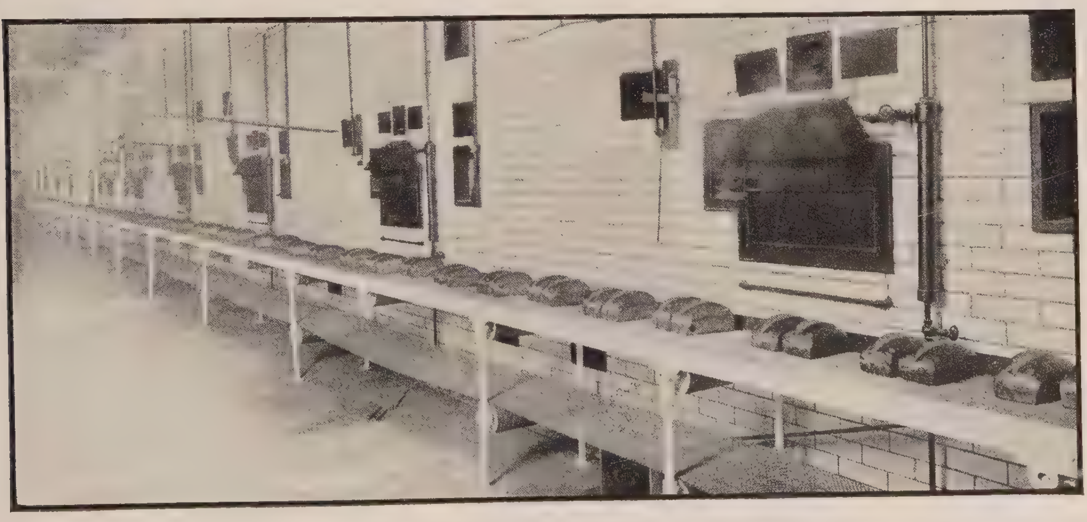
When the mixing process is completed, the dough is emptied into large steel receptacles mounted on wheels, and set away in a special room to rise. A man with a thermometer takes its temperature occasionally, and at the right moment it is passed into another room and deposited upon a curious machine which weighs out the precise amount required for a given kind of loaf and neatly cuts it off. Another machine then takes it and performs the process called "kneading," which the housewife must do with her hands. When the balls of dough are ready, they are slipped into pans piled on a wheel rack. These are trundled away to a steel-lined room filled with steam, where the temperature is kept at one hundred degrees Fahrenheit the year round. Here the dough gets its second "rising," after which it is ready for the ovens.

IN THE OVENS

Every large baking concern has a long battery of huge ovens, each of which will accommodate from three hundred to three hundred and fifty loaves of bread at one time. The ovens are built of brick and the walls are made very thick, in order that they may hold the heat a long time. Often the fire is permitted to go out for a day or two, but at the end of that time the bakers must still watch the ovens carefully or the bread will be burned. Gas is now used to a large extent in place of coal or coke, which for a long time was considered the best fuel for bakers' ovens. Each oven is illuminated by a powerful electric light in order that the baker may see all parts of it. Before the loaves are removed, the oven is flooded with steam for a few minutes for the purpose of giving the crust of the bread the glossy appearance which we all like to see and which the housewife secures, when she makes bread in the kitchen range, by rubbing it over with butter or with cold water.

PREPARING THE BREAD FOR DISTRIBUTION

Bread should be distributed as soon as possible after it is baked. But in the business of distribution the baker meets, as he has met at all stages of the preparation, the problem of insuring absolute cleanliness. If we are to allow our bread to be made outside our homes, we must be certain that it is made and handled under healthful conditions. In many modern bakeries absolute safety in distribution is obtained by labeling and wrapping each loaf separately. To do this an ingenious machine has been devised into which the loaves are fed as they come from the oven, and from which they issue completely wrapped and sealed, ready for the delivery wagons. In some shops the loaves are placed on an endless chain belt as soon as they come from the oven and carried to the wrapping room. Besides the local delivery, huge quantities of bread are shipped by train and truck, sometimes to places hundreds of miles away.



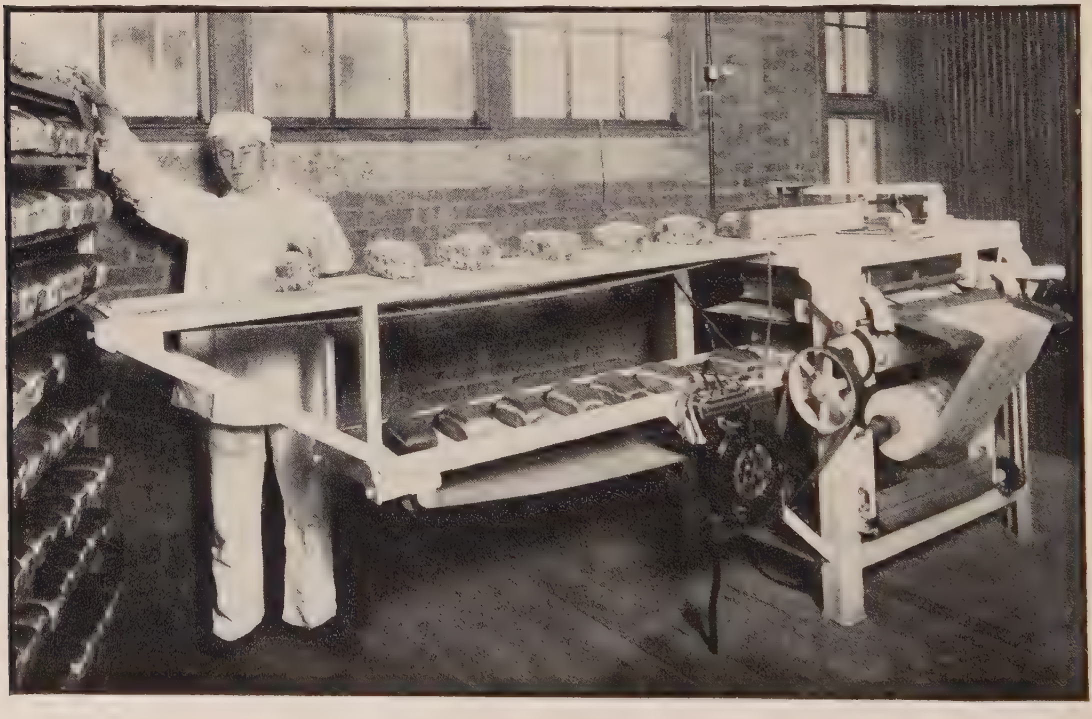
BREAD JUST FROM THE OVENS TRAVELING ON AN ENDLESS BELT TO THE SHIPPING ROOMS

WHAT KINDS OF BREAD ARE EATEN IN OTHER LANDS?

Each nation has its own special bread and wonders how people can eat any other kind. The German peasant considers our white bread insipid in comparison with his great black loaf, which is always sour. It is a custom in German villages to have a single large oven to which each housewife may take her batch of dough. These ovens will often hold fifty or sixty loaves. In Finland the old custom was to have one baking day in the year, when a great number of rye cakes were made up, each with a hole in the middle through which it could be strung on a cord and hung up until needed.

In Central America, Mexico, and even in parts of the United States the tortilla is the principal article of diet. It is made of corn meal and water and worked with the hands into exceedingly thin wafers. These wafers are baked one at a time on a sheet of metal over a bed of coals or even on a hot stone, and when a dozen or so have been placed in a pile, they are rolled up and eaten. The Pueblos of New Mexico make what are practically tortillas, although white visitors call them sheets of "paper bread." They are really almost as thin as a newspaper. The squaws like to color them red, blue, or green, thinking that this makes them more appetizing.

Strange materials are sometimes used in making bread. Icelanders make flour from reindeer moss, which is dried and pulverized. Beans, acorns, and roots are used in various parts of the world. Some of the Indians in the western part of our country make acorn flour. In parts of Europe fish meal is added to barley meal. It is a common practice in the United States to use potatoes in white bread. Rye and barley bread are popular with European immigrants, and many of them like caraway seeds in their bread. We have learned from our foreign neighbors to enjoy different kinds of bread, and our bakers are now providing us with many more varieties than they did a few years ago. As we study the grains and find out what valuable foods they are, we realize that it is greatly to our advantage to cultivate a taste for these different kinds of bread.



A BREAD-WRAPPING MACHINE AT WORK

WATERMELON TIME

FRUITS AND VEGETABLES

FRUIT RAISING

THE raising of fruit is one of the greatest industries of the world. Since the earliest times known to man, fruits have grown wild; but it has taken centuries for him to learn which are useful as food, and how to cultivate them. The many delicious varieties which we now have are the result of much patient labor and experiment. Through man's scientific study of Nature's ways and his intelligent application of her principles, flavor has been improved, size increased, and in many instances seedless varieties developed, all of which makes the fruits more valuable to us.

If we stop to consider just what fruit is, we shall find it to be that product of a plant, bush, or tree which contains the seeds. It grows for this purpose, and, together with the plant and its blossoms, lives only for this end. Some of the things we call vegetables, such as squashes, cucumbers, tomatoes, and peas, are in reality fruits. Fruits are classified under three general heads: orchard or tree fruits, vine fruits, and small fruits. The tree fruits have four subdivisions: pome fruits, the seed formation of which is like that of the apple and pear; drupe fruits which have a single stone, like the plum, peach, and cherry; citrus fruits which include the orange, lemon, lime, and grapefruit; and nuts, fruits with hard shells. Small fruits include berries of all kinds, and the grape is practically the only representative of vine fruit.

HOMES OF THE VARIOUS FRUITS

The United States is remarkably rich in fruits. With the exception of a few kinds, we raise in abundance every sort which we require, and have much to export in addition. The

Mediterranean countries also produce a vast supply — oranges, figs, olives, and grapes growing luxuriantly in the hot sun; there, however, many of our American fruits do not thrive. England excels in raising strawberries and gooseberries, but other fruits require so much cultivation there that only comparatively small quantities can be sent to the markets. France, like Italy and Spain, is famous for its vineyards, and there was a day when we depended on these countries for most of our grapes. Now, however, California supplies over two million tons annually, and a great many are grown in New York and Michigan.

Both Florida and California give us pineapples, and some of this fruit is shipped in from the West Indies. Our greatest supply, however, is in canned form; its source, the Hawaiian Islands. Peaches we have in largest quantity from California, with many from Georgia also. Delaware, New Jersey, and Michigan are other important peach-raising states. Pears, plums, and cherries are grown in many different sections of the country, California taking the lead.

In the Southern sections of the United States, watermelons form an important crop. Georgia, Florida, Texas, California, and the Carolinas are the states which lead in their production. Cantaloupes are shipped in great numbers from California, Arizona, and Colorado.

Of the berries, the strawberry and cranberry are of the greatest importance commercially. During the late winter and early spring months, long before native strawberries are ripe in the Northern states, extensive shipments are made from Alabama, Louisiana, Florida, Arkansas, North Carolina, Texas, and Missouri. The growing of cranberries is confined almost entirely to three states — Massachusetts, New Jersey, and Wisconsin. Raspberries and blackberries are raised in almost every section of the country and marketed locally, for they are too soft to be satisfactorily transported. A start has been made in the cultivation of blueberries, but the greater part of those which we consume grows wild.

The avocado, or alligator pear, is a fruit which has come into prominence in recent years. It was previously classed with the rare fruits, but is now raised in considerable quantity in both California and Florida. The alligator pear bears no relation to the true pear except in shape. It is a fruit of the drupe class, having one large stone. The skin is hard, dark green or purplish in color, and shiny. The flesh is yellowish green, and of the consistency of firm butter.

Other unusual fruits are being cultivated to a much greater extent than was formerly the case. To-day a well-stocked market is likely to show, in addition to the staples, such varieties as pomegranates, prickly pears, persimmons, mangoes, and kumquats.

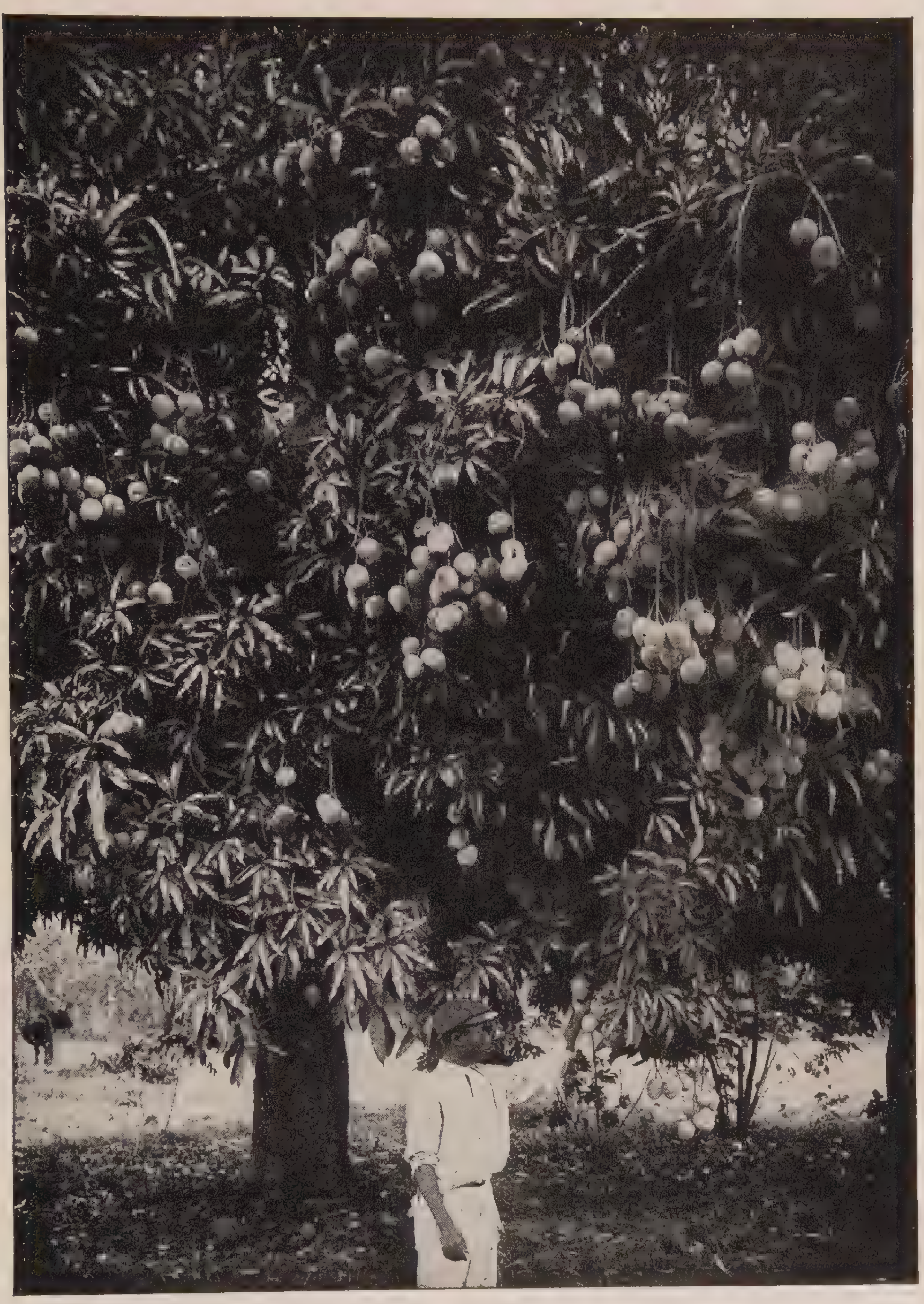
In sections of the country where large quantities of fruit of any one kind are raised, coöperative associations have been formed among the growers. In these organizations problems common to all the members are considered, new methods of culture studied, and standards for quality established. The associations also maintain packing stations, and handle the marketing of the produce.

The fruits which we consume in largest quantities are apples, oranges, and bananas. The growing of each of these is an industry of sufficient importance to be discussed separately.

APPLE GROWING

OF all the fruits which we raise, the apple is the most widespread. It is not, however, a native fruit. It was introduced in 1629 by early settlers, and in a short time apple trees were growing on every farm. As pioneers pushed westward they carried apple seeds with them in order to establish orchards wherever they made their new homes. Much was done toward propagating the fruit in the early days of the nation by an odd character, called Johnny Appleseed. It was his custom to scatter apple seeds on every piece of fertile, well-watered land to which he came in the course of his travels. Many orchards of western Pennsylvania and Ohio are said to owe their start to this Johnny Appleseed.

At present the United States is the greatest apple-growing country of the world. Washington is far in the lead of all the other states; New York is second in importance. Other states which produce large apple crops are Virginia, Illinois, West Virginia, Pennsylvania, California, Oregon, Idaho, Ohio, North Carolina, and Arkansas.



Courtesy Royal Mail Steam Packet Co.

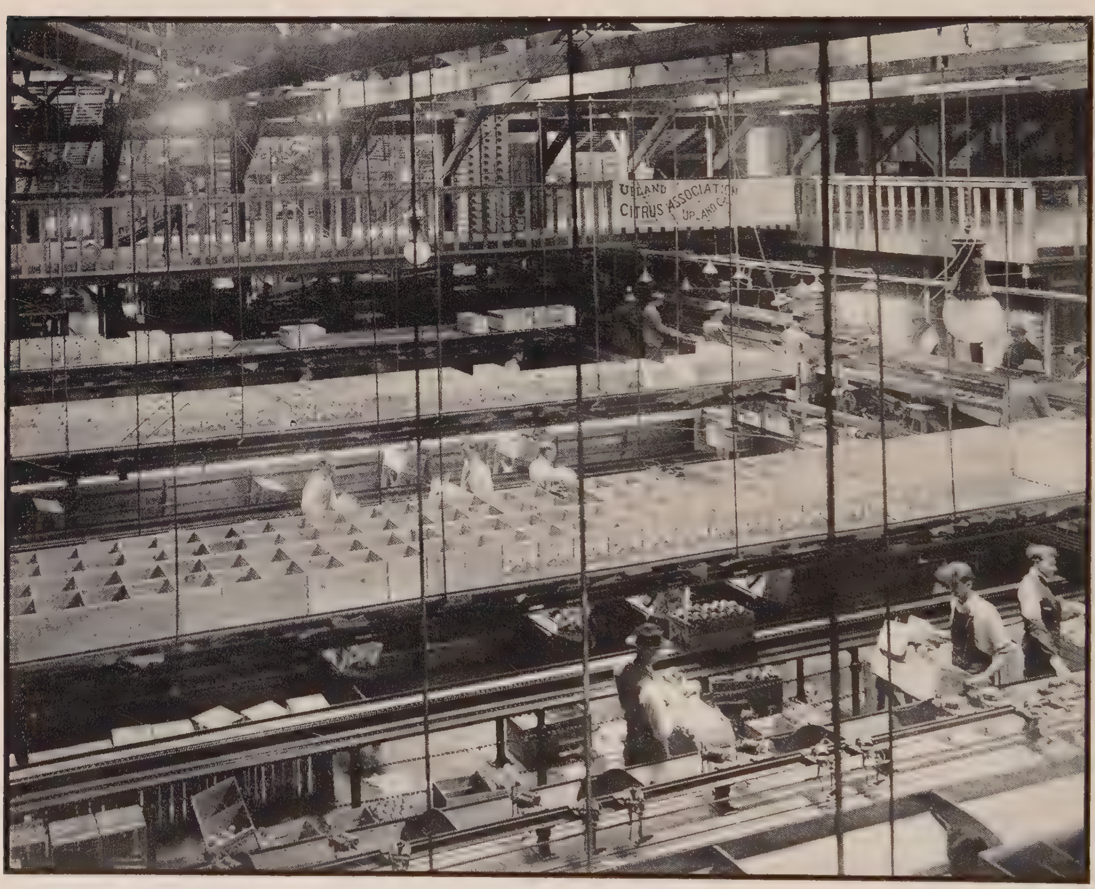
A BUMPER CROP OF MANGOES, JAMAICA

The mango is a delicious fruit of tropical and subtropical regions. Most of the mangoes in our markets come from the West Indies, but some are raised in Florida and California.

Apple trees grow readily, and in most sections of the country there is hardly a farm without its apple orchard. For profitable production, however, scientific cultivation is essential. Since apples grown from seed are invariably inferior to the original fruit, it is necessary, in order to produce apples of high quality, to graft onto the seedling trees buds from trees known to yield particularly good fruit. This grafting is done in nurseries; later the young trees are transferred to orchards where they are planted in rows from 30 to 40 feet apart. The trees are pruned, as they grow, to keep them from reaching too great a height. Sprays and other treatments are used to overcome diseases and insect pests. During the early part of the season the soil around the trees is cultivated. Later may be planted crops of clover, alfalfa, or cow peas, which, when they have grown, are plowed under to enrich the land.

Apples are carefully hand picked, sorted, and graded according to quality and size. The barrel, which for many years, was commonly used for packing apples, has been replaced almost entirely by a box holding a much smaller quantity.

About a hundred different varieties of apples are grown in this country, but not all of them thrive in any one place. In the South apples which ripen early have been found most successful, while the Northern states produce larger proportions of the late varieties. Modern cold storage plants make it possible for us to find apples in the market every month in the year, but long storage destroys the fine flavor of fresh fruit.



PACKING HOUSE FOR ORANGES AND OTHER CITRUS FRUITS, CALIFORNIA

Courtesy of California Fruit Growers Exchange

PICKING ORANGES IN A CALIFORNIA ORCHARD

THE STORY OF ORANGES

ALTHOUGH the orange tree is of tropical origin, it has been found that fruit better adapted to commercial purposes may be produced in some parts of the United States than in the tree's native environment. California is the most important orange-growing section in the world; next comes Florida; then Spain, Italy, and South Africa. California produces over half of all the oranges consumed in the United States and Canada.

Probably no crop in the world is more carefully cultivated than the oranges grown in the United States. Methods for improvement are constantly being sought, and everything possible is done to produce high-grade fruit.

The orange tree begins with the planting of seed for rootstock in sheltered seed beds. Some hardy citrus variety is chosen which is not readily attacked by diseases. At the end of a year, when the seedling trees have reached a height of a foot, they are transplanted to a nursery, and after a year or two longer a bud, cut from a twig of an older, bearing tree is grafted on. From this the orange tree now develops, the original top of the rootstock tree being cut off. No matter what kind of rootstock is used the fruit will be the same as that of the tree from which the bud is taken; a lemon or grapefruit rootstock will produce oranges if the graft is from an orange tree. In about a year after the budding operation the young trees are transplanted to groves. The soil is carefully cultivated and fertilized all through the lifetime of the tree, and where rainfall is not adequate to supply the necessary moisture, as in California, the groves are irrigated. The

Courtesy of California Fruit Growers Exchange

HOW ORANGES ARE PROTECTED FROM COLD

When frost threatens the orange crop, the orchards are warmed by oil-burning heaters placed between the rows of trees.

trees are frequently pruned and the branches trained; fumigation and spraying are used to eliminate insect pests. In winter when cold nights threaten to do damage to the fruit, the temperature of the groves is raised by oil-burning orchard heaters, placed between the rows of trees.

Six years after planting, an orange grove begins to bear a crop of commercial value. At the end of ten years it is considered to be full bearing, but if the trees are given proper care they will continue to increase in size and productivity for many years more.

If the fruit is to be marketed successfully it must be picked and handled with great care. Although the skin of the orange is so thick and seems so tough, it is very easily bruised, and bruising quickly leads to decay. Each orange must be carefully clipped from the stem by workers who wear gloves to avoid injuring the skin of the fruit with their finger nails, and from the tree to the packing house the fruit is handled as gently as eggs would be.

After it reaches the packing house, the fruit is allowed to stand a day or two so that some of the moisture of the rind will evaporate. Then it is given a warm-water bath followed by a cold rinse, and is dried by a blast of air. Next, it is passed along on an endless automatic belt, past expert graders who examine it minutely and separate it into classes according to the special requirements for the different grades. Often the best grades are indelibly stamped with a brand name.

Sizing is the next step. This is done by a machine which separates the oranges into ten different lots, ranging from 80's to 324's. These figures refer to the number of oranges packed in the standard box. Skillful workers wrap the oranges, one by one, in tissue paper and pack them in the boxes, placing each according to a certain geometrical arrangement which insures the proper number to a box. Before the boxes are ready for shipment they are taken to a special room where the fruit is cooled. Finally, cars which are refrigerated in summer and heated in winter bring the oranges in good condition to the markets in all parts of the country.

OTHER CITRUS FRUITS

Lemons and grapefruit are two other members of the citrus fruit family which form important crops in the United States. California produces practically all of the lemons used in this country and in Canada; a small proportion is imported from Italy. Florida leads in the production of grapefruit, but many are raised in California and Texas. The industry has more recently been developed in Arizona also.

The culture of these two fruits is similar to that of oranges, and they are handled after picking in much the same way. The finest lemons are picked while still green and allowed to ripen, or cure, in cool rooms. Grapefruit, also, are sometimes stored and cured before shipment.

HOW BANANAS ARE RAISED

MUCH as we enjoy eating bananas we are likely to think of them as one of the most commonplace of fruits; we can buy them inexpensively in our markets at all seasons and have them very frequently on our tables. Yet in the development of the banana industry is found one of the most fascinating romances of modern business. It involves remarkable scientific achievement and affects the lives of thousands of people. It is responsible for improved sanitary conditions and control of disease in the banana-growing regions; it has given health and a means of livelihood to the natives; it has turned worthless jungles into productive land.

Little is known about the early history of the banana, but its use as a food reaches into remote times. Probably the fruit originated in the tropical regions of southern Asia, where, history tells us, the armies of Alexander the Great, in 327 B.C., found it growing abundantly. It was early discovered that the root would flourish in suitable soil and climate even though dried and carried great distances. Consequently, the banana is found to-day in all the humid tropical regions of the world.

Credit for bringing the fruit across the waters to the New World is given to the Reverend Father Tomas de Berlanga, a Spanish priest. He came in 1516 as a missionary to the island of Santa Domingo, bringing with him roots of banana plants from the Canary Islands. Later, he became bishop of what is now Panama, where he also introduced the fruit. Other missionaries followed his example, and it became the custom, wherever a mission was established, to insure a food supply by planting bananas.

Bananas were brought to the United States, probably from Cuba, early in the nineteenth century. With only occasional small shipments, the fruit was regarded as a rare tropical luxury. The great development of the industry came with the end of the century.

The principal exporting regions are now the

Courtesy of United Fruit Company

A BUNCH OF BANANAS READY FOR HARVESTING

When we see a bunch of bananas in market, it is usually hung so that the fruit points down, but as the bunch grows the bananas turn upward. The leaves of the plant have been cut away to give a clear view of the fruit.

countries touching on the Caribbean Sea, Mexico, and the Canary Islands. Brazil, Ecuador, Peru, Chile, Queensland, Australia, Java, and the Fiji Islands also export small quantities. It is in the region along the Atlantic coast of Central America, extending a few miles back from the Caribbean Sea, where conditions of soil and climate are ideal for banana culture, that the greatest banana plantations in the world are located. These have been developed by American capital and industry and from this section the United States, as well as many European countries, receives its tremendous supply of the fruit. Here a vast tropical wilderness has been turned into a tract of cultivated land. Railroads have been built, telephone systems put into operation, steamship service established with United States ports. For the benefit of employees, food stuffs and merchandise have been imported, and well-equipped hospitals are maintained.

ONE METHOD OF TRANSPORTING BANANAS

As soon as bunches of bananas are harvested they are loaded on the backs of mules and carried to the railway.

We think of bananas as growing on trees, but the banana "tree" is really a huge plant, somewhat like our canna in structure. It grows from a rootstock, called a "rhizeme," on which develop large buds or eyes similar to the eyes of the potato. By the planting of a piece of rootstock containing an eye a new plant is started. From the eye, leaves shoot up, forming what looks like the trunk of a tree but is in reality a compact mass of overlapping leaf-sheaths. The tree grows rapidly until at the end of a year it is from fifteen to thirty feet high and has large drooping leaves. By the end of the tenth or eleventh month a large flower bud has pushed up through the center of the leaf-sheaths. This bud opens to show a cluster of purplish flowers. As the blossoms go by, the stalk bends over and hangs down, looking like a huge ear of corn in its husks. The outer coatings soon drop off, leaving the bunch of bananas revealed. At first the fruit points downward, but as the bananas grow they turn upward. A bunch of bananas is made up of *hands* or clusters, each containing 10 to 20 individual bananas, or *fingers*. A six- to nine-hand bunch is most readily marketable. After the blossom appears, it requires about four months for the bananas to develop to the proper stage for cutting.

Bananas are always cut from the tree when they are green, even when they are to be eaten by the natives. Unlike most fruit, which is at its best when tree-ripened, they lose their flavor, the skins burst open, and the pulp is attacked by insects.

So necessary is it that the cutting and shipping of bananas be accomplished with speed, that the main office in the United States communicates by radio with the head office of the tropical divisions when a steamship is about to land, and from there orders are telephoned to district headquarters and quickly transmitted to the overseers of the individual farms. As each bunch of bananas is cut, it is carried on the shoulders of a native to the nearest pack road or tram station and loaded on the back of a mule or into a tramcar for the journey to the railway. Here the bunches are packed in cars and taken to the port where the ship is waiting. The holds of the banana ships are specially constructed so that conditions of temperature and moisture can be controlled; otherwise, the fruit would spoil during transportation. At the end of the journey, the bananas are unloaded into cars which can be heated or cooled according to the season and are carried quickly to all parts of the country. When the wholesale distributor receives them, he puts them into ripening rooms, kept at 62° to 68°, for quick ripening, or at 56° to 62°, if the fruit is not needed so soon. The

Courtesy of (Dole) Hawaiian Pineapple Company

A HAWAIIAN PINEAPPLE FIELD

Above: Planting pineapple slips through mulch, a kind of paper. Below: Rows of pineapple plants when the fruit is fully ripe.

time required for ripening is from four to nine days, and the process is one of the most important in the long chain of steps between the plantation and the retailer.

HOW PINEAPPLES ARE GROWN IN HAWAII

THE pineapple, so called because of its resemblance to the pine cone, has been grown in tropical countries since ancient times and has long been valued for its refreshing qualities and pleasant flavor. It is important commercially in the West Indies, California, and Florida; but Hawaii is known as "pineapples' paradise." Here the soil and climate are especially well adapted to its growth. Thousands of acres of land are devoted to its culture and thousands of tons of fruit are harvested every year. By far the largest part of the Hawaiian crop goes immediately to the canneries which have been built in close proximity to the fields. The industry has been developed by Americans and is conducted along most modern and scientific lines.

After the pineapple fields have been thoroughly worked and are ready for planting, they are laid out in blocks with lanes between. Next, long rows of "mulch," an asphalt paper somewhat like sheathing paper used in building, are laid down, spaced four to six feet apart. This is to prevent the growth of weeds which flourish all too readily in the tropical climate, to give protection from the burning sun, and to keep the ground from drying out. Pineapple slips are then planted through holes in the paper. In a few weeks these slips take root and begin to send out leaves. It takes about a year and a half for the plant to mature and bear fruit, and while it is growing the space between the rows is carefully cultivated, fertilizer is applied, and a tonic of iron solution is sprayed on the plants. The blossom, which appears in 12 to 15 months, is like the pineapple itself in appearance, with a number of tiny blue flowers growing out from it. Gradually the flowers wither and the fruit develops. When it has reached just the right stage of ripeness — experienced pickers can tell when this stage has been reached by the sound which they hear when they tap the pineapple with their fingers — it is broken off at the stem, ready to be taken to the cannery. Pineapples which are to be shipped some distance to markets must be picked before they are fully ripe.

The pineapple plant is cut back after the first crop is harvested, and then it bears again, usually a heavier crop than the first. After a third crop has been harvested, the land is plowed for replanting.

THE DRIED-FRUIT INDUSTRY

DRIED fruits are almost as old as the human race. The records of the Egyptians are the first to tell about raisins, but it must have been centuries before the first mention of them in writing that men discovered that grapes left on the vines and dried in the hot sun had a delicious flavor and could be kept from one harvest time to the next. As the population of the world has moved westward, the art of fruit drying has moved with it, until now it is one of the most important industries in California, where fruits are grown in abundance and the hot summer sun is ideal for drying.

Ambitious and far-sighted growers have toiled to produce the kinds of fruit best adapted for drying, and to adopt the cleanest, most efficient methods. So successful have they been that California, although it has been settled for less than a century, is now shipping raisins and other dried fruits to the very sections of the world which first knew them. The Joachim and Sacramento valleys produce most of the raisins used in the world to-day, far surpassing Spain which for many years held the lead. Dried peaches are almost exclusively an American product, and dried apricots are an important product of California. Until recently, most of the world's supply of prunes came from France, Spain, and Central Europe. Now, California and Oregon are engaged extensively in their production. Many figs are still imported, coming from Greece, Spain, Portugal, Italy, and Asia Minor, but California is increasingly able to supply the domestic market. The fig industry is being developed also in Texas and Arizona. Dates have more recently been added to the dried fruits of the United States. They are grown in some parts of California and in Arizona.

The process of fruit drying is extremely simple; yet the greatest care must be taken to produce a fine product, and complicated machines have been introduced to bring about production on a large scale. Take raisins, for example. Only the sweetest and thinnest-skinned varieties of grapes can be used, the White Muscat and Thompson Seedless proving most satisfactory. Ordinary, thick-skinned, native American grapes would make dry, shriveled little raisins, sour and flavorless. Again, the grapes must be picked at just the right stage — when they are sweetest and ripest. They are cut from the vines in bunches, laid on trays between the rows, and exposed to the hot sun. After a few days they are turned so that they will dry on the other side. Next, after being allowed to stand in large containers so that moisture will be equalized, they are sorted according to sizes, washed and dried, and put through a seeding machine. A final step, before packing, is sterilizing.

In a similar manner dried peaches, figs, apricots, and prunes are prepared; the details of the process vary slightly according to the nature of the fruit. Peaches must be cut in halves before they are exposed on the drying trays, and they are put through a process which removes the fuzzy, tough skin. Prunes are dipped in a hot lye solution, then rinsed, to break the skins so that they will dry more readily. Drying by artificial heat in appliances called "dehydrators" is sometimes used for prunes instead of sun drying.

When we come to dates, we find that the processes of production are a little different from those of the other dried fruits. The fruit is left

A DATE PALM GROWING IN SOUTHERN CALIFORNIA on the tree to dry and the hot sun literally bakes the sweetness in. The date, when fresh, is something like a plum in appearance, plump and smooth-skinned. It varies a good deal in size and color, depending on cultivation.

Dates were probably first grown in Mesopotamia. They are a common food in Egypt, and an important source of wealth as well. There is a story that when Alexander the Great marched with his army through Arabia into Egypt, he carried quantities of dates as rations for the soldiers. Wherever they stopped they left many date pits, or stones, and in the years that followed, the line of march could be traced by the trees that had sprung up. It is said that these trees can be seen growing even now about the oases in the deserts of Africa and Arabia.

The date palm is now cultivated in the dry districts of the southwestern United States, where the climate is too hot and dry and the soil too alkaline for other crops.

NUT GROWING AS AN AMERICAN INDUSTRY

UNTIL quite recently our nut supply was made up entirely of importations and varieties that grew wild in different sections of the country. Now there are four kinds of nuts cultivated in such quantities as to give nut growing a place among the industries of the nation. These four varieties are peanuts, English walnuts, pecans, and almonds.

PEANUTS

The peanut is probably a native of tropical America. It was little known in the United States until after the Civil War. A few peanut plants were cultivated, chiefly as a curiosity, in gardens in the Virginias and Carolinas. During the war-time scarcity, soldiers discovered that the nuts made excellent food. Following the war, commercial cultivation began. To-day nearly two million acres of land are devoted to peanut growing. Virginia, Alabama, North Carolina, Texas, Florida, and Georgia all raise the nuts. Altogether, millions of bushels are produced every year.

Peanuts are really vegetables, although they so resemble nuts that they are usually considered with this class of fruits. The peanut grows in the ground instead of in the air, and is borne by a vine, not a tree.

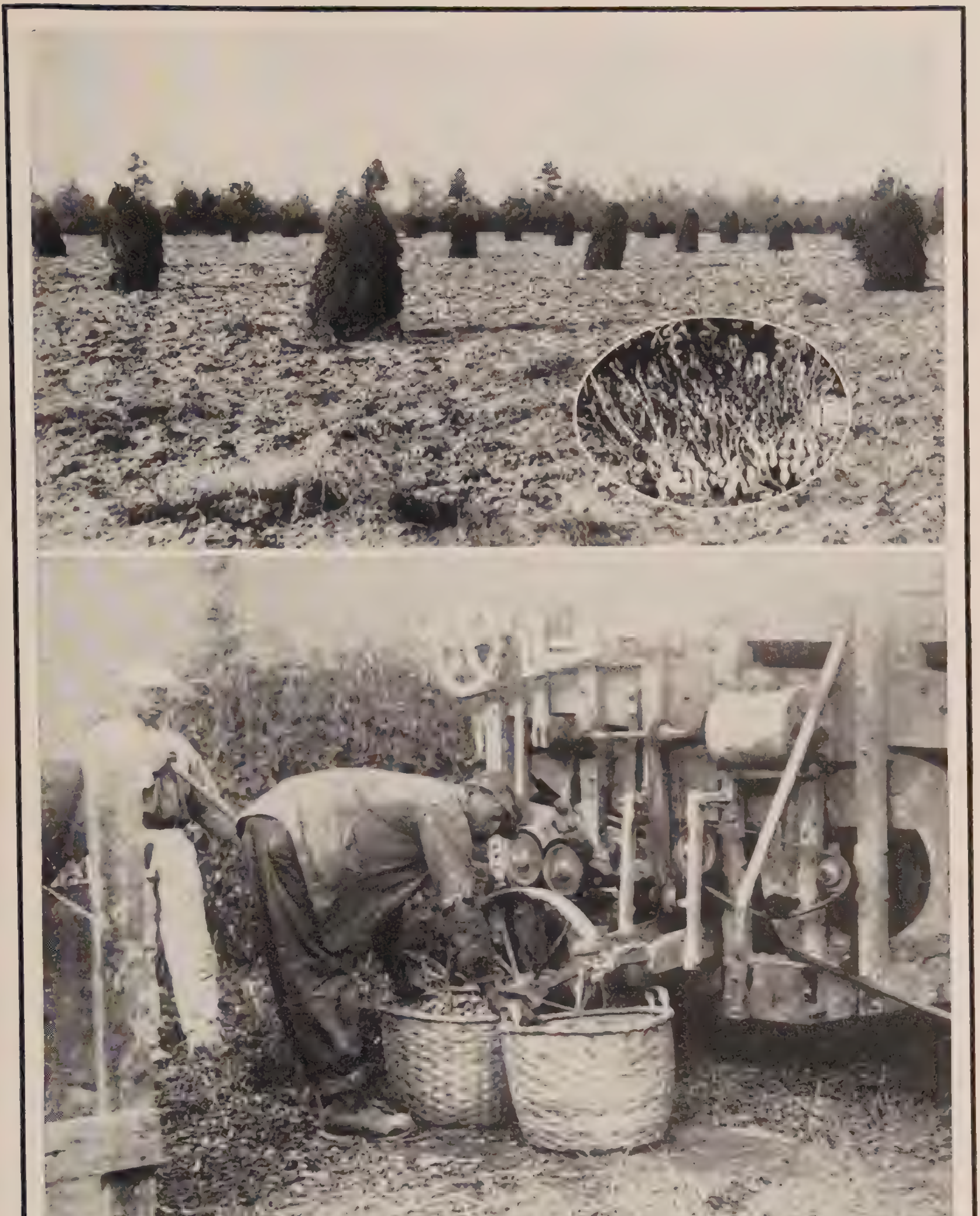
After the blossom of the peanut plant has withered, the flower stalk, bearing the very young pod, bends downward and forces its point into the soil. There the nut develops and ripens. When harvest time comes, the vines are dug and laid on the ground to dry for a short period. Then they are stacked for curing, with the peanuts in the center of the stacks to prevent discoloration from rain. After that, the nuts are removed by machinery from the vines, cleaned, graded, and given a final polishing. The whole peanut plant is utilized. The vine is used for cattle feed, and the roots which are left in the ground serve as fertilizer.

WALNUTS

The English walnut, which is the variety important commercially, is not English at all, but of Persian origin. The name which we use was given because the nut was first imported by way of England. The climate of California has proved to be ideal for the growth of this walnut, and it is extensively cultivated there. In fact, California at present supplies a large proportion of our total consumption. Sixty million bushels was the output for a recent year.

In walnut growing, as in other branches of agriculture, high quality is the result of the care used in cultivation. The trees are not just planted and left to grow by themselves; constant watchfulness and ceaseless toil go into the production of the finest nuts. Grafting is the most satisfactory method of propagation of the walnut tree. A young shoot, called a "scion," or a bud from a bearing tree is grafted onto the rootstock.

When the nuts are ripe they fall to the ground naturally, or are shaken from the trees. After being husked they are either taken to the curing yards and laid out on shallow trays in the sun, or cured in dehydrating machines by artificial heat. The latter is a time-saving method which is coming more and more into favor. Cleaning, bleaching, and grading are further steps in the preparation of the nuts for the market. Finally, the finest walnuts go through a branding machine which leaves its stamp on each nut.



Ewing Galloway

GROWING PEANUTS IN THE SOUTHERN STATES

Above: Peanut vines stacked for drying. The insert shows how the nuts grow at the roots of the vines. Below: Peanuts coming from a threshing machine.

PECANS AND ALMONDS

While the walnut industry has been developing in California, other states have brought pecan growing into prominence. Of the 5,000,000 bushels produced in one year, Texas raised the greatest proportion. Oklahoma, Georgia, Mississippi, Louisiana, Alabama, North Carolina, Arkansas, and Florida also play an important part in the industry

The pecan is a native of America, growing in abundance along the lower Mississippi and its tributaries and in the river valleys of Texas. As people traveled in earlier days from one part of the country to another they planted the nuts in new sections. This accounts for the presence of the tree in places where it was not originally found. Though many of the nuts from the trees which grow wild find their way to our markets, the output from planted orchards is steadily increasing. Propagation by grafting or budding, together with careful cultivation, has improved the quality of the nuts and made the industry profitable.

The almond is a nut native to the region east of the Mediterranean Sea, but it has long been grown in southern Europe and Asia. Now it is cultivated in South Africa, Australia, and California as well. California produces practically the entire crop raised in this country. The annual output averages between 15,000,000 and 20,000,000 pounds.

OUR INCREASING VEGETABLE SUPPLY

THE vegetable-growing industry in the United States has developed during recent years in a phenomenal fashion. It was not long ago that individual farms and market gardens were the sole source of the fresh vegetable supply of the country, each one disposing of its crops in nearby cities and towns. During the winter months root vegetables that could be stored without spoilage and the products that had been canned had to be depended on entirely.

Later came the hothouses in which a summer-like temperature was created by means of steam. These made possible a limited supply of fresh things, but much expense was involved, and hothouse products were not for people of ordinary means.

Local gardens and truck farms still furnish much fresh produce in season, but the large distributing centers now have supplies from all parts of the United States; and there is not a retail market in a city of any size which is not filled with a variety of fresh vegetables all the year round. This state of affairs is due to the development of large-scale production in new areas which can supply fresh products in the seasons when local crops are not available. Desert regions have been transformed by irrigation into mammoth vegetable gardens, and during the winter and early spring, shipments

A PRIZE CROP OF SQUASHES

Keystone

LARGE-SCALE PRODUCTION OF CELERY IN FLORIDA

are made on a gigantic scale from California, Texas, Arizona, and Florida. The west coast of Mexico is also being developed and much produce imported from there. In other states, Colorado in particular, conditions are favorable for late fall crops. Peas, cauliflower, lettuce, and cantaloupe are the products supplied in quantity at this time.

Quality is being constantly improved by agricultural studies and experiments, and improved methods of grading, packing, and handling are bringing better and better products to our markets.

The potato can still be called our most important vegetable. It is the one produced in largest quantity in the United States, and is one of the most valuable of the world's crops. One acre of potatoes, it has been estimated, will furnish as much food for human beings as ten acres of wheat.

Although they have spread all over the globe, potatoes belong to the New World. The Spaniards found the Indians of South America eating them, and carried samples back to Spain. At first the potato was fed to hogs, but the people of Ireland began to eat it in a period of famine, and their early use of the vegetable on their tables explains the name "Irish potato."

The sweet potato is an important crop of the South. It is also grown as far north as Pennsylvania, and to some extent in New Jersey and Illinois.

Records of the United States Department of Agriculture show that next to potatoes, lettuce is the crop of greatest importance, if shipment by carload lots is used as a guide. California and Arizona are the states in which this vegetable is produced on the largest scale.

Thousands of carloads of green peas and of tomatoes are shipped long distances to the big city markets each year. The states of Texas, Louisiana, Mississippi, California, and those along the south Atlantic coast do a vast business in bunched carrots during the winter gardening season. Fresh cabbage comes all winter from Florida and the lower Rio Grande Valley, while Texas furnishes the Eastern markets with tremendous quantities of spinach.

TEA GATHERERS, NEAR KYOTO, JAPAN

THE FRAGRANT TEA

" Polly, put the kettle on,
And we 'll all take tea."

TEA drinking is a very old Chinese custom; just how old we do not know. Long before anyone else had heard of tea it was in use among both the Chinese and the Arabs. Certainly the Arabs were using it as early as the ninth or tenth century. But it was not until 1610 that the first tea was brought from China into England, where it sold for four dollars a pound. Later a trading ship came bringing four thousand pounds of tea. The English, however, did not know how to use it, and it took them many years to find out. A story is told of how some English people invited their friends to have tea with them and cooked the tea, drained off the water, and served the leaves with salt and butter. Do you wonder that their guests did not like the taste of the new dish?

Yet at the present time, in other countries, tea is still served in many surprising ways.

In Tibet it is stewed with pork, salt, flour, and milk; after cooling, it is eaten as if it was some sort of porridge. The Russians pickle tea, or drink it cold with lemon in it, holding a piece of sugar in their mouths to sweeten it. Natives of other lands chew the tea leaves, and some mix them with sugar and cook them into a sirup. Tea is now such a common drink that it is hard to realize that there was a time when people did not have it. It was not until the eighteenth century, when tea drinking became popular in England, that the custom was taken up in America and other parts of the civilized world.

TEA PLANTS AND WHERE THEY GROW

Although the tea plant was originally a Chinese shrub, a different variety of it was found to be growing in Assam, India, and it is from these two kinds that our tea comes. The Chinese plant is not so tall as the Indian, for it is usually only from three to five feet high; the Indian species, if not clipped, often grows to be fifteen or twenty feet in height. But since tea must be picked by hand the tea bushes are kept low so that the pickers may reach the branches easily. Both trees are evergreens, the leaves on the Chinese plant being about four inches long, while those of the Indian variety are sometimes as long as nine inches. Chinese tea plants are stronger and more easily grown, and therefore are more in demand. And yet tea is by no means a difficult plant to raise. It will grow in almost any soil, but of course in the warm, moist earth of the tropics it thrives best. It has, however, been raised in England and even in North Carolina. The chief difficulty is that, as all the work of cultivating, gathering, and preparing it must be done by hand, it is a very expensive crop to harvest in countries where labor is not cheap. In India, China and Japan, where living is simple, natives can be hired for very little. Twice a day the tea gatherers, some of them often being children, bring the tea they have picked into the factories, where their baskets are weighed.

Pickers are paid by the pound, a quick picker frequently gathering from twelve to eighteen pounds a day; many do not gather as much as this. A few cents pays for the labor of picking.

HOW TEA IS RAISED

Tea is started from seed, and when well up the small plants are transplanted and set out in rows. The plants must then grow about three years before they are old enough to be of use. When they are older they throw out offshoots called "flushes"; these flushes have seven or eight leaves, some small, some larger. The leaves of the new shoots are the only ones gathered for market. As soon as one set of flushes is harvested another set grows, until as many as twenty-five sets of new leaves follow each other on a single plant. The finest tea is made from the tender leaves, and in China these are generally gathered in February or March, while still protected by a fuzzy white down called *pakho;* it is from this word that we get the word *pekoe* — the name of one of our most expensive varieties of tea. The cheaper

Courtesy Chase & Sanborn

PICKING GREEN TEA LEAF

teas are made from the larger, tougher leaves of the plant. In some countries tea harvesting goes on all the year, seasons for picking differing with the climate.

Before marketing tea, therefore, you can readily see that the leaves must all be sorted. Sometimes this is done when they are picked, but more often the gatherers take off the entire tip of the branch and the leaves are sorted according to size afterward.

HOW TEA IS PREPARED FOR SALE

The first step in preparing Chinese and Japanese tea is to spread it in large trays and leave it in the air. Here it soon begins to ferment, and it is this fermentation which decides the flavor of the tea. Men trained in preparing tea can tell by the odor exactly how long to let the leaves lie in the air. Think what a difficult task that must be! It is while the tea is fermenting that some of the tannic acid in it is turned into sugar; it is this sugar that helps to give the tea its flavor.

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TEA PLANTATION AND RICE FIELDS, JAPAN

When the leaves have aired long enough they are put into dishes and slowly roasted over a hot fire of charcoal. Then they are taken off and the natives roll them in their hands to squeeze out the juice. Afterward they are again roasted and again rolled, and this is done over and over until the moisture is out of them. They are then spread on sieves over a fire and stirred and turned until entirely dry. The black color comes in this last drying, although it has been preparing to do so throughout the whole process.

The tea is then packed in lead-lined boxes or chests, that none of its flavor may be lost, and it is ready for shipping.

In olden times tea used to be brought across the deserts by caravans, and it was a wonderful sight to see great processions of camels, laden with oriental merchandise, making their way from the East; but now we employ the fastest ships to carry tea, as buyers feel that even at best the tea loses some of its flavor in transportation.

Green tea is manufactured by much the same process as black tea. Its green color is due to the fact that the leaves are not allowed to wither, but are quickly roasted while fresh.

HOW THE NATIVES OF INDIA PREPARE TEA

In India tea is prepared differently from what it is in China. After it has been picked, aired, and fermented it is made into damp balls and workmen roll and knead it on tables. Then it is pressed into great lumps and put away to ferment again. When it has fermented long enough it is either roasted over a hot fire or dried by machinery. Afterward it is sifted, sorted, and sealed for market.

PRICES OF TEA

There is a vast range in the price of tea. Coarse teas can be bought for a low price; teas made from the flowers of the tea plant, however, often cost from sixty to eighty dollars a pound. The most costly teas are packed in glass, brocade, or lacquer boxes fastened with bits of ivory or silken cord, and look much more like caskets of jewels than packages of tea.

Courtesy Chase & Sanborn

TOP: WEIGHING THE GREEN TEA LEAF PICKED DURING THE DAY. BOTTOM: WEIGHING TEA

COFFEE TREE WITH RIPE BERRIES

THE EXHILARATING COFFEE

THERE are many interesting stories of how people first found out that coffee was good to drink. One of them is that very long ago an old Arab sheik wandered into Persia and was there taken very ill. A Persian sage brewed for him a drink made from the berries of a wild herb growing in the fields, and this strange hot beverage brought about the recovery of the Arab.

After he became well again he returned to his own land, carrying with him some of the berries of the shrub that had cured him. These berries he planted, sharing them with his friends. Thus was coffee introduced into Arabia.

Whether there is any truth in this story it would be hard to say. Certain it is, however, that coffee drinking had its origin with the Arabs. Since the Koran forbade them to drink stimulants made from alcohol, they no doubt were glad to find this substitute. In the sixteenth century the Turks and Arabs in Constantinople were all familiar with the use of coffee, and carried the custom with them to Venice, then one of the great cities of the world. From Venice it traveled to Paris. Later London welcomed it with open arms. In the seventeenth century the coffee house was the popular resort not only of the idle and fashionable men of the time but of scholars and statesmen as well. Here people congregated, sipped a cup of steaming coffee, and discussed the news of the day, the coffee houses occupying much the same position then that a gentlemen's club now holds.

America was the next country to take up coffee drinking. The English have since reverted to tea, and use it much more generally; but coffee is still the popular drink on this side of the ocean.

HOW COFFEE GROWS

In Peru, Persia, and western Africa coffee grows wild in the fields. It takes its name from Caffa, a town in Abyssinia, where its valuable properties were first noticed. It is now widely cultivated in India, Arabia, Mexico, and Brazil, the latter country alone supplying more than half the coffee used by the entire world. You notice, therefore, that it is in the tropics that coffee has its home. It needs heat, richly fertilized soil, and very deep earth in which to grow.

Like the tea plant, coffee is started from seed, and when large enough is transplanted in rows from six to eight feet apart. Until coffee plants send out branches which can shelter their own roots they must be cared for constantly. This danger point safely passed, they become quite hardy. In growing the plants the same plan is followed as in pruning tea bushes. The tops of the shrubs are cut in order that branches may be forced to shoot out at the side. This is for the convenience of the pickers, who must gather the coffee berries by hand.

Although some young coffee plants blossom and yield fruit in the second year, they cannot be relied upon to do so until the third. Then, when spring comes, beautiful white blossoms with a strong, sweet perfume bloom on the coffee plants.

When this bloom drops it leaves a small soft seed on the stem, which is not unlike a cherry in formation and size. The soft part of this fruit is useless, but in its center are two coffee berries which fit together and make a sort of stone. These are what you have so often seen roasted and ground.

As soon as the blossoms of the coffee plant

GATHERING COFFEE IN BRAZIL

More than half the world's coffee comes from the plantations of Brazil. When picked the berries are dark red like cherries.

WASHING COFFEE IN BRAZIL

All that remains of the outer pulp must be rinsed off the berry.

DRYING COFFEE IN THE SUN, COSTA RICA

fall, and the cherries ripen, pickers are turned into the plantations, and move from one plant to another, gathering the dark red and slightly shrunken cherries in bags. These bags the pickers afterward empty into a common receptacle.

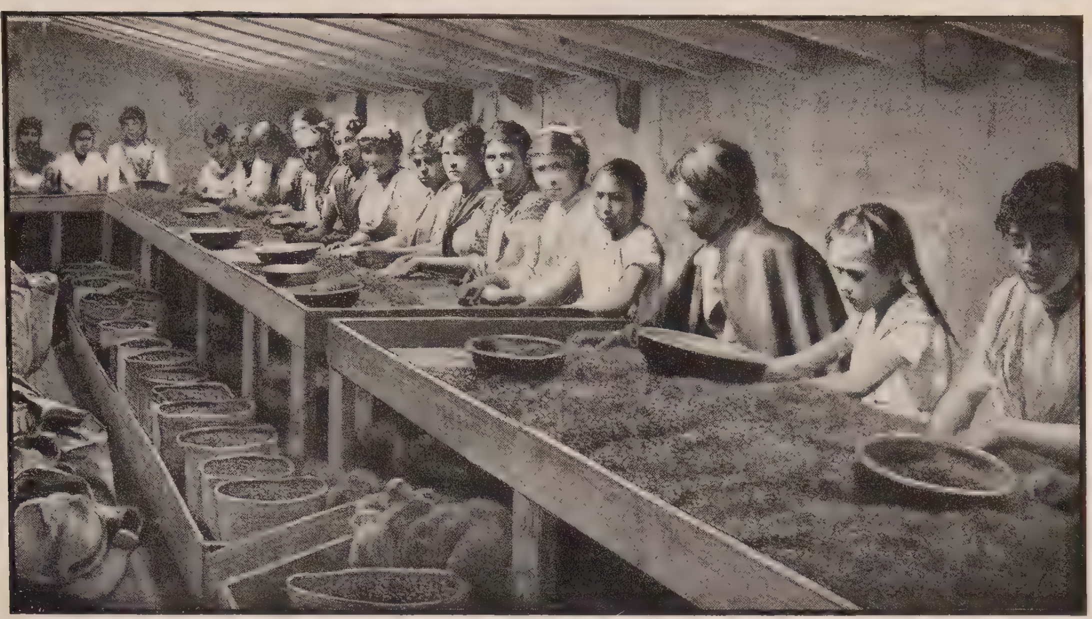
Picking is slow work. When a picker gathers two or three bushels of cherries a day he is doing well. Since only the ripe cherries are gathered, the pickers are constantly obliged to retrace their steps and glean the rest of the fruit as fast as it matures. This work is hard and poorly paid.

TURNING THE DRYING COFFEE, ARNABA, MEXICO

After the cherries are gathered the coffee berries must be taken out of the center. This is done in a mill. Sometimes it is possible to float the cherries down to this mill through pipes of running water. If they are sent down from the hillsides in this way large sieves, or screens, are placed at the ends of the pipes to filter off the water and collect the fruit. The pulp, or soft part of the cherry, is removed by placing the fruit between revolving disks which tear it apart and separate it from the coffee berries. Some manufacturers think this should be done promptly before the soft pulp has a chance to ferment. Other growers let the pulp dry on, and later remove it by machinery. When the cherries are dried in this fashion they are put in the sun and stirred until the pulp shrivels. They can then be shipped to distant mills.

ASSORTING COFFEE, NICARAGUA

This is a convenient process and is especially favored by those growers who either cannot afford mills, or have not the facilities near at hand to run them. When the pulp is not allowed to dry on but is removed from the fresh cherries, much soft matter clings to the coffee berries; the easiest way to get this off is to let it ferment and then rinse it off with water.



Courtesy Chase & Sanborn

HAND-PICKING COFFEE

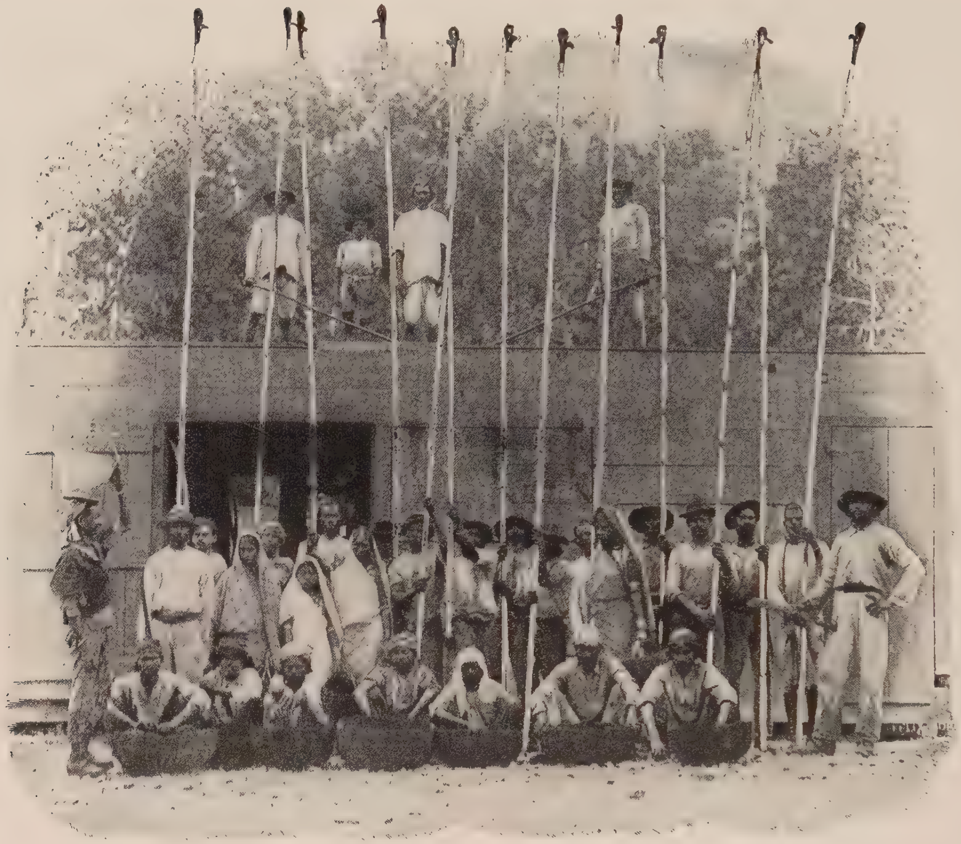
The clean coffee berries, or beans, are then dried by the sun or by means of hot air. When the bean is dry a thin coating, not unlike the inside skin of the peanut, covers it; this is known as the "silver skin," and it is removed by rolling the beans until it cracks off. The beans are next placed in a sorting machine which drops those of the same size into boxes. The raw coffee — or, as dealers say, "green coffee" — is now ready to be shipped. No coffee is ever roasted before shipping, as it soon loses its flavor. Green coffee, however, may be kept indefinitely.

When the coffee reaches the factory, it must be roasted in order to develop the flavor which makes the beverage so pleasant. During this process the beans swell somewhat, and the color is changed to dark brown or almost black, depending upon the severity of the roast. After it has been roasted, it should be used as soon as possible. Some coffee is ground at the factory all ready to be used, and some is marketed in the bean, to be ground by the grocer or in the home.

Since coffee loses its flavor very quickly if exposed to the air after it has been roasted and even more rapidly when it has been ground, it should be put up in air-tight packages, and the movement from factory to consumer should be as rapid as possible.

To produce the finest flavored coffee several varieties of beans are blended together. The varieties are so chosen that some special characteristic lacking in one will be provided in another. For instance, Mocha and Java make a choice blend, for the Mocha berry is highly acid while the Java coffee is not acid enough to be pleasing.

TEA AND COFFEE PLANTS



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GROUP OF NATIVE COCOA PICKERS

THE REFRESHING COCOA

WHEN Cortez came to Mexico he found the Mexicans making a delicious drink that he and his followers had never before tasted. In fact, so fond were the Mexican people of this beverage that Prescott, the historian, tells us that the Mexican king Montezuma, who lived in great splendor at the capital, often had as many as sixty jars of the drink made for him and his court; it was served very hot and taken from golden goblets. Upon investigation it was found that this new dainty was prepared from the seeds of a kind of tree growing in the tropical parts of South America. The Mexicans called it "cacao," and it was nothing but the well-known cocoa which we all like so much.

Cocoa grows on a small tree, or shrub, from fifteen to eighteen feet high, having large, smooth leaves and clustering flowers of pinkish white. Sometimes these flowers blossom on the branches, sometimes shoot out of the trunk of the tree itself. Strange to say, they do not blossom all at one season, but continue to bloom at intervals during the entire year. Consequently the fruit is maturing all the year round, although the principal times for gathering it are in June and December.

HOW CACAO TREES ARE SET OUT AND GROW

Cacao trees are grown on plantations similar to those where coffee is cultivated, and like coffee plants the cacao trees are also raised from seed. Cacao plants, however, are rather delicate and are not transplanted from the nurseries until they are about two feet high;

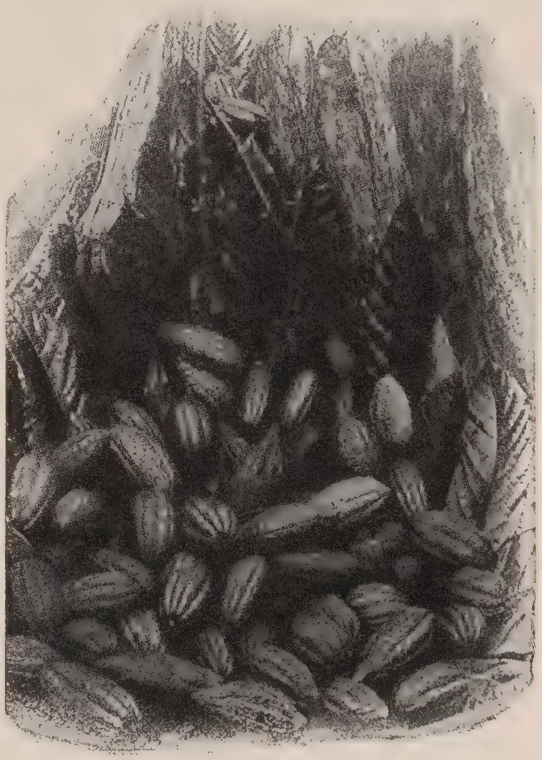
even then they must be protected from hot sun and strong winds. In order to shelter them the growers often set out hardier things in the same field, that these may cast their shade over the cacao plants and at the same time serve to break the force of the winds. Until the fourth or fifth year not much fruit can be expected from the young cacao trees, and it is not until the eighth year that they really bear a good crop; but when they have once begun to yield a harvest they go on bearing abundantly for from thirty to forty years. After the cacao trees have flowered each flower sends out a pod not unlike a cucumber in construction; each of these pods is from seven to ten inches long, and has inside rows of cells filled with sweet pulp. Embedded in the pulp are from five to ten seeds. Some pods will contain twenty-five or even fifty of these seeds altogether. The seeds are about the size of an almond.

GATHERING AND PREPARING CACAO

Laborers travel up and down through the rows of cacao trees selecting the pods which are ripe, and cutting them off by means of knives mounted on long handles. As soon as the pods fall the workmen catch them that the fruit may not be bruised, and heaping them in piles leave them for at least a day to dry; the pods then soften and it is easy to cut them open and take out the seeds.

COCOA PODS AND LEAVES

As is the case with both tea and coffee, fermentation aids greatly in the preparation of cocoa and has much to do with its flavor. The seeds ferment either in sweating-boxes or in the ground for two or three days, when they are placed in the sun and dried; it is then that the cacao beans gradually turn the beautiful chocolate brown color that you are accustomed to see. After drying they are shipped to the market in bags.



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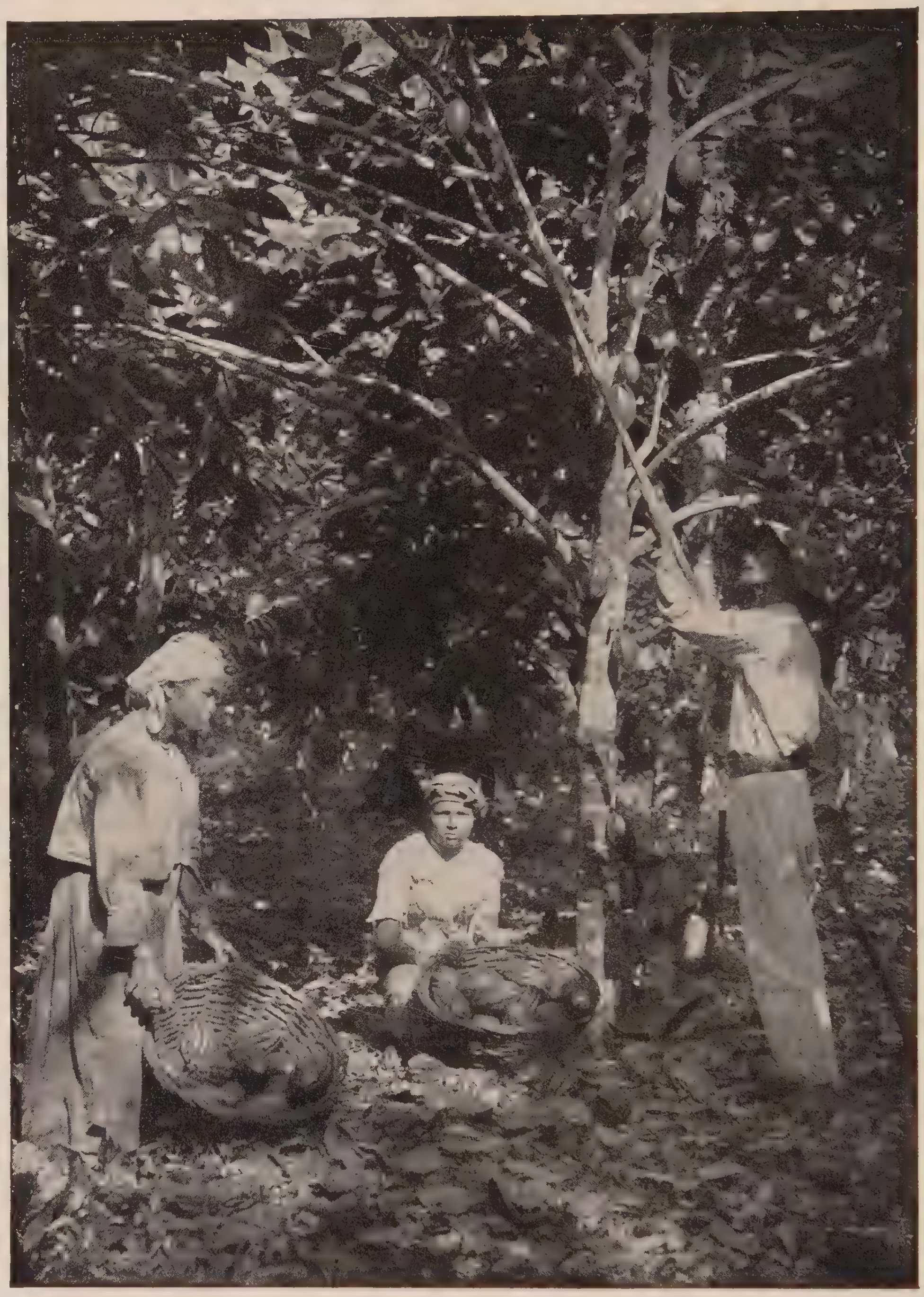
COCOA PODS, EACH SEVEN TO TEN INCHES LONG

Before using cocoa, however, the seeds must be roasted in revolving cylinders and afterward placed in machines which crush them into small pieces called "nibs." Then the pieces of cracked cocoa or nibs must be separated from the shells by blasts of air. It is necessary, as a last step in the process, to sift the nibs, or have them



Courtesy the Royal Mail Steam Packet Company

GATHERING COCOA AT TRINIDAD

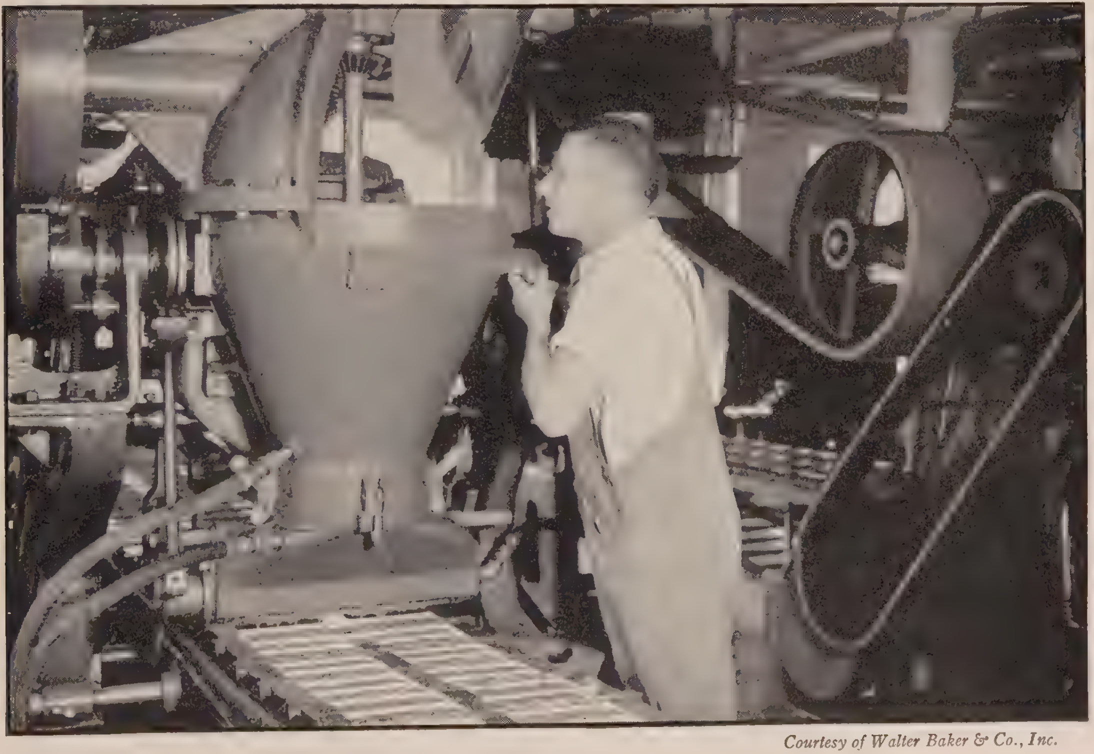
The ripe pods are cut by knives on long handles, then gathered and heaped in piles to dry, when the seeds are taken out.

Courtesy of Walter Baker & Co., Inc.

A STEAM ROASTER FOR COCOA BEANS

sorted by hand, that all impurities may be taken out.

Cocoa can be made from the nibs by boiling them a long time, but as it is found to be much easier to make the drink if the nibs are ground to a powder, this method of preparation is generally in use. The powdered cocoa is put in sealed containers to prevent the moisture getting in and making it damp or lumpy. You all know without doubt that when the powdered cocoa is mixed to a paste, pressed down between heavy rollers, and hardened in molds it is called "chocolate." Chocolate may be unsweetened, or sweetened with sugar and flavored with vanilla. You also know the many pretty shapes into which chocolate may be fashioned, and the delicious things that can be made from it. Think for a moment of the chocolate creams, bonbons, and caramels we eat during the year!



Courtesy of Walter Baker & Co., Inc.

AUTOMATICALLY WEIGHING CHOCOLATE FOR MOLDING

These chocolate candies are not altogether bad for us if we do not eat too many of them at a time. In fact, so great is the food value of chocolate that persons going on long walks or on journeys frequently carry it in place of food. It is also in use among mountain climbers, and has an important place in the food rations of armies and exploring expeditions, because of its nourishing qualities and because it can be carried in such small space. Dr. Nansen, the famous Arctic explorer, in his book, "The First Crossing of Greenland," speaks of the large use made of chocolate by the members of his party. Cocoa beans are about half composed of a rich fat which, when extracted in manufacture, is made into cocoa butter — a healing remedy much employed by physicians. Since a portion of this fat, as well as more or less starch, is found both in cocoa and in chocolate, it is not difficult to see why they are valued as foods.

Although the Mexicans used cocoa so long ago, it was not until 1657 that it was at all known in England. We read that at that time there was in London a fashionable resort — a kind of coffee house — called the Cocoa Tree, where hot chocolate was served. About the beginning of the eighteenth century chocolate had become an exceedingly popular beverage, and the cocoa tree was then a favorite sign and name for the places of public refreshment. Chocolate was first manufactured in this country in 1765, in the State of Massachusetts. At the present date the French, Germans, British, and Dutch use far more cocoa than do the Spanish. This great supply for the world comes chiefly from our Western Hemisphere, the Caracas cocoa from Venezuela being considered the best.

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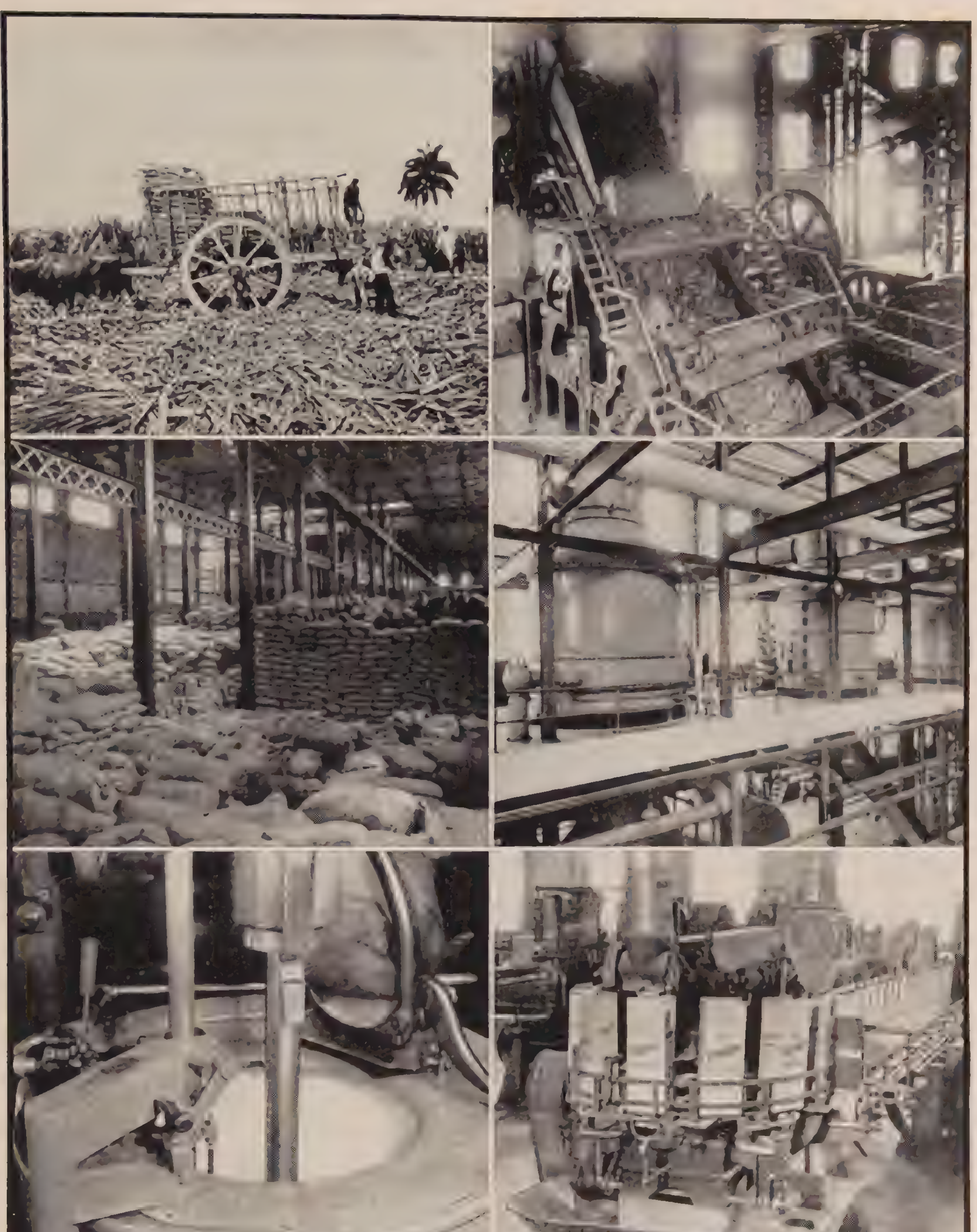
SUGAR — FROM CANE TO CRYSTAL

HOW would you like to have lived in the days when tea and cereals were sweetened with maple sugar, brown sugar, or honey, and when white sugar was such a luxury that no one thought of using it commonly, but kept it for a treat or a medicine? Such days were not very long ago. Our colonial ancestors knew them well. At that time money was not so plentiful as it is now and, as but little sugar was made, and most of this came from other countries, people could not afford to buy it. Sometimes the children were allowed to have it on their bread, or eat some of it in place of candy. Perhaps mothers realized that sugar is needed by all children as fuel for their bodies. The children, of course, did not dream that more than half their energy was generated from the sugar taken into their systems, nor know that this was the reason why they wanted it just as our children do today. Americans eat several times as much sugar as the people of Europe eat. In fact the United States has become the greatest sugar-eating nation of the world. On an average each person eats in some form or other about eighty pounds of sugar a year — much more than the Germans or French. It is only because the English use so much to make jams that they approach this record. One reason why so much sugar is used in America is be-

American Sugar Refining Co.

MOLDING SUGAR LOAVES, SEVENTEENTH CENTURY



American Sugar Refining Co

UPPER LEFT: HARVESTING THE CANE. UPPER RIGHT: GRINDING AND PRESSING THE CANE. CENTER LEFT: RAW SUGAR IN BAGS. CENTER RIGHT: REMOVING IMPURITIES IN VACUUM BOILERS. LOWER LEFT: EXTRACTING THE CRYSTALS IN CENTRIFUGAL SPINNER. LOWER RIGHT: PACKAGING THE FINISHED PRODUCT.

Courtesy The Louisiana Planter

SUGAR CANE GROWING IN CUBA

cause in the United States almost everyone can afford it. No other people use it so commonly in food, or eat such quantities of it in candy. Certainly we do not lack fuel to create the energy for which we as a nation have become famous. But not all the fuel taken into our bodies comes to us through ordinary white sugar. There is some sugar in almost every growing plant, and therefore much in other foods which we eat. Grapes contain a great deal; so do milk, maple sap, beets, the juice of the palm tree, and the sugar cane. From all of these sugar may be extracted, but it is from beets and sugar cane that we get the most.

WHERE SUGAR CAME FROM

Centuries ago sugar cane grew only in southern Asia, and it was the Chinese alone who found out what to do with it. They did not make sugar like ours, but they did use the sap for sweetening purposes. The other peoples of the world used honey. It was the Crusaders, those fighters who brought so many wonderful new things back into Europe, who first carried sugar cane to northern Africa and later to Madeira and the Canary Islands. For many years the sugar for all Europe came from the Canary Islands. Then the Western Hemisphere was discovered and plantations were started in the West Indies. South America next took up the industry, and later it spread to the tropical districts of the United States. Now most of the cane sugar raised in our country comes from Louisiana and the delta of the Mississippi River. Since, however, we consume so much, there is not enough to fill our demand even with the addition of the beet sugar we make, and we are forced to import a great deal from Porto Rico, Cuba, the Philippines, and Hawaii.

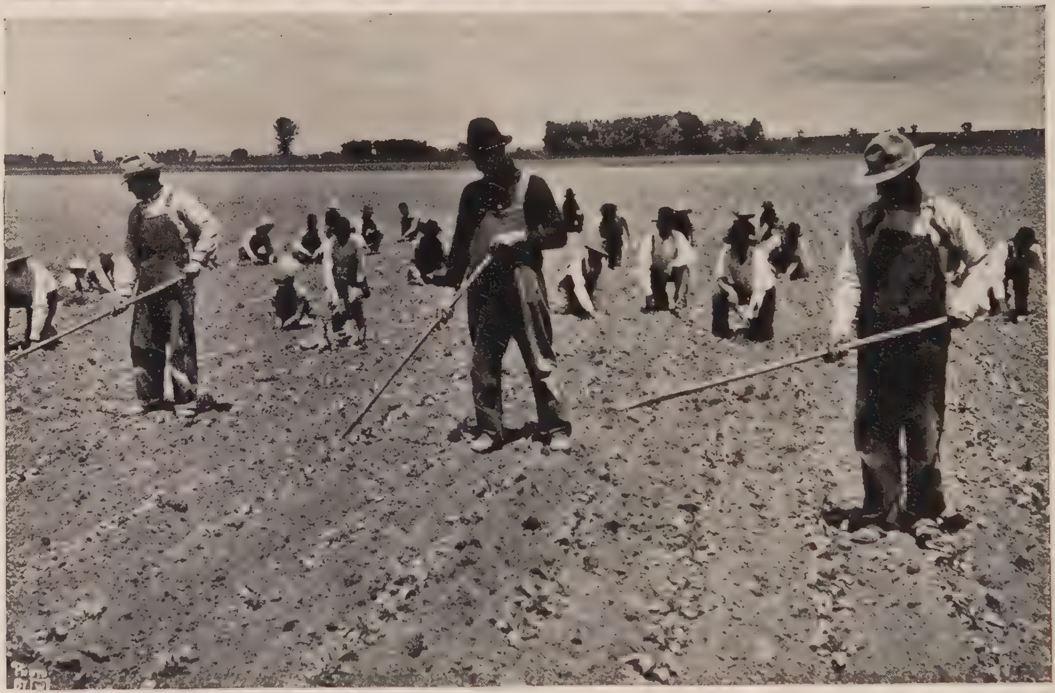
HOW SUGAR CANE IS PLANTED AND HARVESTED

In planting cane on great plantations, the fields are first plowed; then wide furrows, about seven feet apart, are made. Into these furrows are laid long, freshly cut pieces of sugar cane, three abreast. These are covered and soon sprout from the joints, just as potatoes sprout from the eyes. It takes a year for a cane crop to mature. When grown it is higher than a man's head and so thickly interlaced that one can scarcely make his way through it. When it is large enough, men and women with long knives cut the stalks close to the ground, it being well known that the most sugar is found nearest the root. This done, the leaves and tops are taken off and the stalks tossed in heaps which are collected and carried to the train in carts. Often the cane travels many miles before it reaches the mills. The stumps left on the plantation will usually, in course of time, sprout into two and sometimes three crops called "rattoon" crops. In Cuba, these continue to come up for from fifteen to twenty years, although planting is usually done once in three to five years. In Louisiana, however, rattoon crops cannot grow on account of frost, so planting is done every year.

When the sugar cane reaches the mill it is first squeezed between large, heavy rollers with a rough surface like a grater. Again and again it is crushed, until it comes out so dry that it can be used as fuel in the furnaces of the factory.

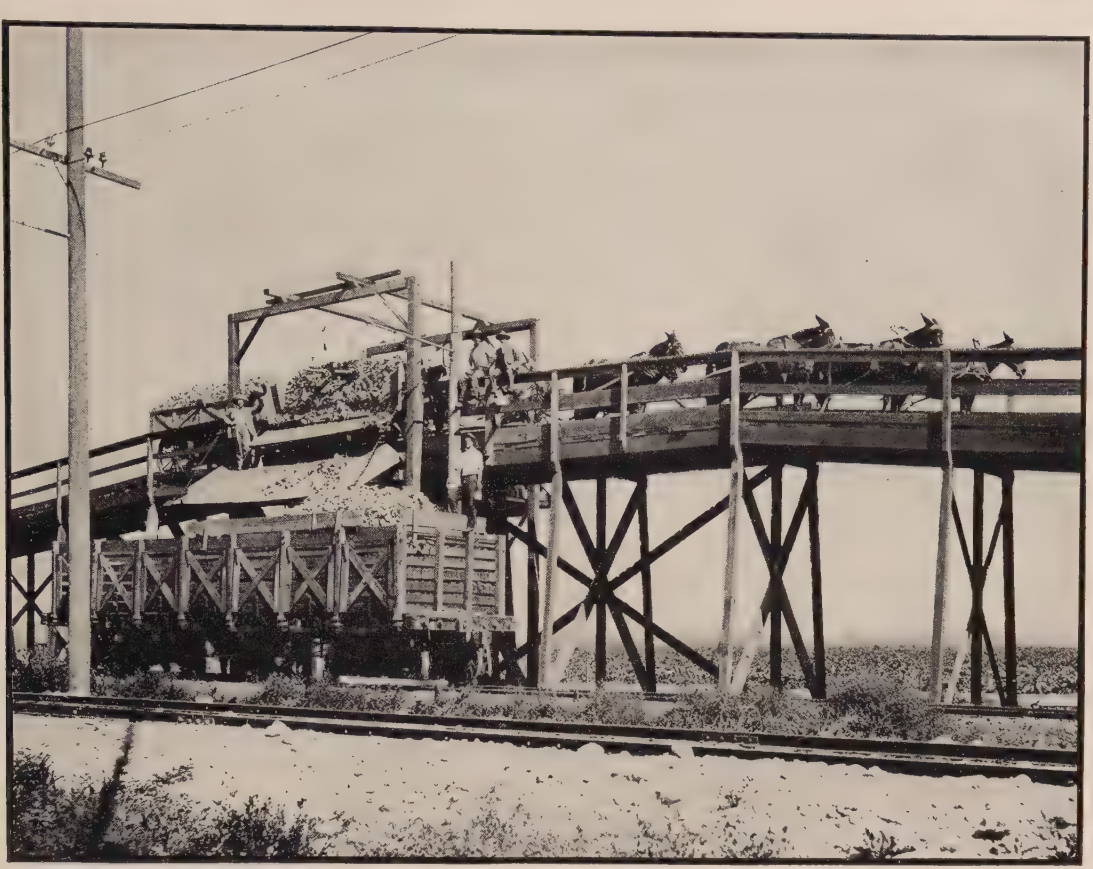
The juice, which runs out into troughs, is not at all tempting either to look at or to taste; it is sickishly sweet and looks like dishwater. How wonderful it is that from this thin gray liquid should come such pure white crystals! Of course, the liquid does not stay thin and gray long. It is poured into great tanks where, by means of sulphur gas, it is made to boil up into foam. Into the scum that collects on the top of this foam rise all the impurities; these are promptly skimmed off. Many times the juice is skimmed. It is then settled by putting lime into the liquid. Afterward it is ready to be boiled into syrup in great copper vats heated by coils of steam. These vats are connected in such a way that the juice can flow from one to another; as it travels along it constantly becomes clearer and thicker until the mass of grains look in it somewhat like brown corn-meal. When it reaches this stage it is drawn from the vats and run into metal cylinders or centrifugal machines which revolve swiftly. These cylinders strain off through their gauze covering a thick brown sirup which, if boiled down, can be made into second or third grade molasses. The best molasses, however, is made from the cane direct, and is known as New Orleans or Porto Rico molasses; it is not necessarily made in those places. While the sticky juice is being forced through the gauze by the rapid whirling of the cylinders, fine crystals collect on the inside of the gauze. At first these crystals are brown, but soon they pale and if they have been put in hot enough gradually become as light as a light straw color.

THE FACTORY BEET OF TO-DAY



TOP: BEET FIELD READY FOR THE HARVEST. THIS FIELD YIELDED TWENTY TONS TO THE ACRE. BOTTOM: "BLOCKING" AND "THINNING." THE MEN IN THE FOREGROUND ARE "BLOCKING" THE BEETS, LEAVING A BUNCH OF THEM EVERY EIGHT INCHES. THOSE IN THE REAR ARE "THINNING," OR PULLING UP SUPERFLUOUS YOUNG BEETS, LEAVING ONE IN EACH PLACE, EIGHT INCHES APART

Beet sugar photos are reproduced by courtesy of Truman G. Palmer.



A BEET-RECEIVING STATION

Such is the process of producing so-called "raw sugar" from the sugar cane as it has been described to us by one of the leading sugar growers, and as it is practiced on many plantations and in many mills. But in this inventive age no process of production is carried on long without changes and improvements. New machinery has been installed in many establishments by which evaporation is made to play a larger part in the process. In all our sugar-raising countries — in Cuba, Porto Rico, and Java, in Brazil, Peru, the West Indies, Queensland, Argentina, and the Philippines — the sugar cane is being cultivated on huge plantations, and the sugar mills are busy with the processes of extracting the juice and crystallizing the product. In the refinery the "raw sugar" must go through many more complicated processes. It must be washed and melted; the insoluble impurities must be eliminated; it must be filtered, crystallized, dried, and sorted, before there will emerge the granulated sugar of our most common use or the confectioners', loaf, or other special sugars.

BEET SUGAR — THE SUGAR OF THE TEMPERATE ZONES

Sugar cane flourishes only in tropical or semi-tropical regions. Sugar may be profitably extracted also from the sugar beet, which is not a tropical product, but can be and is cultivated in vast stretches of our own country, — as in Colorado, Michigan, California, Oregon, Utah, Nebraska, and Wisconsin, — and in Germany, France, Belgium, Austria, Poland, and Russia.

The demand of the civilized world for sugar makes it one of the most interesting of our industrial products. Any one who lived through the period of the Great War came to a realizing sense of its importance, and of the deprivation which every class of society suffers in its temporary and partial withdrawal from the market. Sugar is a most important article of diet to the northerly countries of the world; yet it has been produced in large measure in the southerly regions. Out of the fact of this interchange grow the monopolies, the speculations in sugar crops, and the shortages which are so carefully watched in financial and government circles. For this reason increasing interest attaches to the sugar beet, as a source of sugar supply which can be produced in the more immediate neighborhood of its consumption.

It was in 1747 that a chemist announced that the sugar beet contained the same kind of sugar as the sugar cane. Napoleon gave a stimulus to the industry by offering in 1806 a bounty of a million francs for the satisfactory production of sugar from home-grown plants. The farmers of Europe took up the industry much more rapidly than did those of the United States, but the sugar beet is being grown more and more in our own country.

The sugar beet is usually white and is not unlike the common garden beet. It is planted from seed. When the beets come up they must be thinned so that each one may have plenty of room for its leaves, for it is these leaves that are the sugar factories of the plant. Here, by means of sap and sunshine, the sugar is made. It is then stored away in the root of the beet. When the crop is ready for harvesting, the beets are pulled up and floated in canals to the washing machines, where they are thoroughly cleaned by means of revolving brushes. They are then cut into thin, V-shaped pieces called "cossettes." The cossettes are put into tanks of warm water, and as they bob about the sugar in them goes out into the water, coloring it black, like ink. This is no more inviting than was the murky, gray cane-sap. It is, however, purified in tanks until, by the aid of lime and acids, it comes out clear as water. The remainder of the process — the boiling into syrup and the crystallizing — is in general the same as is followed in making cane sugar, except that it is much more complete. The impurities of beet sugar are entirely removed in the centrifugal machines, and the product, when dry, is white granulated sugar.

THE ANNUAL OUTPUT

When we talk of sugar we are talking in terms of an immense annual crop. The world's annual output of sugar is over thirty million tons. Cuba leads in the production of cane sugar with about three million tons a year. Puerto Rico, Hawaii and the Philippine Islands each produce another million tons. The United States produces less than half a million tons of cane sugar, mostly from cane grown in Louisiana, but in beet sugar our annual crop is close to one and one-half million tons. Sugar beets are grown chiefly in our western states. Colorado, Nebraska, Utah, Idaho and California produce large quantities. Extensive areas of irrigated land are devoted to the growing of sugar beets.

SUGAR FROM CORN

As a source of sugar, corn is increasingly important. Various forms of corn syrup, which are commonly used as table syrups and in cooking, are already familiar to most of us, but we are perhaps surprised to learn that a sugar similar to ordinary granulated sugar is also made from corn.

The official name of corn sugar is "dextrose." It is not so sweet as cane and beet sugars, both of which are called "sucrose" in the sugar family, but it has just the same food value. Dextrose is used extensively by confectioners, ice-cream makers and manufacturers of jams and jellies.

The method of manufacturing sugar from corn is quite different from the process by which it is produced from sugar cane or beets. Instead of being extracted from the juice of the plant, corn sugar comes from cornstarch, a product of the endosperm of the grain. Starches and sugars all belong to the same chemical group, the carbohydrates. Starch is more complicated in composition; sugar is a simpler arrangement of the elements which make it up. By heating starch with water and an acid it is "reduced," or changed to the simpler form, sugar. This is the principle employed in converting cornstarch into corn sugar. Syrup is the first product obtained by the reducing process; then, by evaporation to a point where crystallization occurs, sugar is formed.

AN OLD-TIME ENGLISH BEE SKEP OR STRAW BEEHIVE

HONEY AND THE HONEYBEE

WHEN left to themselves honeybees make their homes in hollow trees or in the walls of houses or even in chimneys, but when they are kept in apiaries, as bee yards are called, the owners provide movable-frame hives so arranged that the insects may be kept under a certain measure of control. In former times straw hives, commonly called "skeps," were used and are still to be found in parts of Europe.

For a long time box hives were used in this country, but they were very crude and there was a heavy loss of bees when the honey was removed. In 1852 Rev. Lorenzo L. Langstroth, a clergyman living in Philadelphia and a student of beekeeping, invented a hive with loose frames, and by so doing revolutionized the honey-producing industry and put American beekeepers at its head. Bee supplies made in this country are now sent over almost all the world.

The modern hive is so arranged that it may be taken completely apart without injury to a single bee. The hive body, which is practically an oblong box, with an opening in front at the bottom, is made in the right proportions to accommodate eight or ten light wooden frames, with two or three wires stretched across each frame. On these frames the bees build the combs which are to hold the honey they store or the eggs the queen bee lays. Each frame, with its comb and with a great mass of bees clinging to it, may be removed at any time through the top of the hive.

The honey which is stored in these combs is left for the feeding of the bees. The beekeeper depends for his supply on surplus honey which is stored in small frames arranged in another box technically known as a "super," this box being set on the hive body in spring when the bees begin to visit the flowers. If the season is good, it may be necessary to use half a dozen supers, one above another, in order to provide room for the honey which is coming in. In this way a hundred or a hundred and fifty pounds may be secured from one colony of bees. A fair average, however, is about thirty pounds a season.

COMB HONEY

Comb honey is stored by the bees in the pound sections offered for sale in the stores, the supers being filled with these little boxes. Larger combs are used when extracted honey is desired. These combs when filled are placed in a whirling machine, in which they are revolved with much rapidity, the honey being thrown out by centrifugal force.

There is a deep-seated belief that the market is flooded with artificial comb honey, but that is a great mistake. Artificial combs have never been made, and comb honey is always pure. It is true that all honey does not taste alike, but that is because it comes from different blossoms. This is the reason, also, for any difference in color. The famous sage honey of California is very light, but the buckwheat honey of New York State is dark in color. It is also true that beekeepers supply a foundation which the bees draw out into combs, but this foundation, which is attached to the frames in very thin sheets, is made only of pure beeswax. Otherwise it would not serve its purpose. It is used as a measure of economy, but many pounds of honey must be gathered to make a single pound of wax.

There are, as you know, two classes of bees in each colony — the workers and the drones. The latter are the males; the former, undeveloped females. In addition there is a queen, the only perfectly developed female in the hive. The workers perform all the labor, gathering the nectar, making the comb, acting as nurses for the young bees, and keeping the hive clean. The drones are loafers, living wholly on the fruits of their sisters' toil.

The queen's sole business in life is to lay eggs, and she attends to this business with commendable zeal and regularity. She may lay from one thousand to two thousand eggs in a single day, aggregating in weight equal that of her body. The queen is not the royal personage the writers of fanciful articles would have us believe. She is, indeed, constantly attended by a retinue of workers, and she is fed on a very rich food, termed "royal jelly"; but the reason lies in the fact that the very existence of the colony depends upon her reproductivity, and the bees realize that she must not be hampered in any way. A queen is valuable for two or three years. Workers seldom live more than two months in the busy season. They literally work themselves to death. If new bees were not constantly appearing in great numbers, the colony would quickly be depleted. The drones meet a tragic fate at the end of the season, for then they are either killed by the workers or are driven from the hive to perish of cold and hunger.

HOW ARE THE BEES HATCHED?

Worker eggs are hatched in three days. Then larvæ appear and are fed five days by nurse bees. The nurse bees seal them over when the five-day feeding period has been completed, and twelve days later full-fledged bees eat their way to freedom. Three days more and they are put to work as nurse bees. Soon after they are dispatched to the fields. If the bees desire to rear a queen, they feed a special food, which induces extra growth and changes the character of the young bee. A prospective queen also has a very large cell drawn out for her. Drone larvæ are fed three days and then sealed for fourteen.

When a bee first emerges from its cell, it is a feeble little insect. It gains strength quickly, however, begins to comb its hair and rub its eyes, and finally starts to eat out of an open cell of honey.

Courtesy of Dadant & Sons

BEES AT WORK ON A COMB

HOW DO THE BEES MAKE HONEY?

What the bees gather from the flowers of garden, orchard, and field is really nectar, which they convert into the honey we eat. Only a minute amount of nectar is secured from a flower, and in its entire lifetime a single bee stores hardly more than half an ounce of honey.

The nectar is taken into the mouth, and by a wonderful arrangement of internal organs is partly changed into honey while the bee is on its way to the hive. Once inside the hive, the insect inserts its head in a cell and deposits its treasure. Cells all around are being filled at the same time, and the bees in the hive set to work to evaporate the excess of water in the thick liquid by rapidly moving their wings, which act like numberless tiny fans. The contributions of many bees are required to fill a cell, but when it is ready it is covered with a capping of wax. There it remains until taken out by the beekeeper, if in a super, or until opened by the bees to be eaten after the flowers have gone, if in the body of the hive. If it is needed by the bees for immediate use, they do not take the trouble to cap it over.

It has been calculated that a quart of honey represents forty-eight thousand miles of flight between the hive and the flowers. With sixty thousand bees in a hive, they may travel a total of four hundred thousand miles in a day. A bee will fly two miles or more for nectar, if necessary, and seems to know by instinct in which direction to start.

The bees gather pollen as well as nectar from the flowers, using it as food for baby bees. A bee has six legs, two of which bear tiny baskets. The pollen grains from the flowers are slightly moistened and at once transferred to these baskets by a most dexterous movement of tongue and different pairs of legs. In early spring thousands of bees having what look like yellow spots on their hind legs may be seen going into a hive. They are carrying pollen to the hive, and sometimes they are so heavily loaded that they lose a portion at the entrance. Beekeepers often feed meal to the bees if pollen is scarce. Sometimes they supply water, too; for if the weather is cold and the bees are obliged to go a long distance for water, they may never get back.

WHY ARE BEES VALUABLE TO ORCHARDISTS?

Of course honey is a delicious and nourishing food, but the value of the honey produced is hardly to be considered when compared with the work of the bees in fertilizing orchard, field, and garden crops. Without bees and other insects which perform a similar service, the world would soon go hungry. Nature has made careful and in some instances highly ingenious provision to make certain that flowers of different kinds are properly fertilized. When a bee enters a snapdragon blossom, for example, the flower closes after it, hiding it from sight. The insect is obliged to rub its back against the part of the blossom which contains the pollen, and some of this pollen is sure to be left on the flower next visited.

In some parts of the world it is necessary to pollenize squashes, cucumbers, and similar vegetables by hand. The owners of greenhouses in which cucumbers are grown in winter keep several hives of bees in these glassed-in gardens, where they may be seen busily at work in the yellow blooms when the ground outside is carpeted with a heavy covering of snow. All flowers are not fertilized by insects, but those which display striking colors or emit a sweet perfume are pretty certain to require their services

WHAT IS SWARMING?

When a colony of bees becomes populous in spring, the insects divide into two parties by a sort of mutual agreement, and one party, with the queen, sallies forth in search of a new home. This is called "swarming," and is the way in which a natural increase is brought about. By providing extra room or by dividing the colonies artificially, beekeepers often prevent swarming, to a certain extent, their purpose being to keep the colonies as strong as possible in order that a large amount of honey may be stored.

After the swarm has left the hive, the bees which remain rear a new queen and go on as before. The swarming bees alight on a tree or shrub close at hand and send out scouts to seek permanent quarters. Meantime the swarm hangs in a great cluster, the bees clinging to each other, and at that stage of the proceedings it is easy to capture them. The beekeeper simply sets an empty hive beneath, with a sheet spread in front, and either saws off the limb or shakes the insects from it. If the swarm is very high, a device on a pole may be used to make the capture. The queen is usually in the center of the mass, and when she runs into the hive the other bees always follow.

Courtesy of A. I. Root Co.

BEEHIVES IN AN ORCHARD

Then the hive is carried to its permanent quarters.

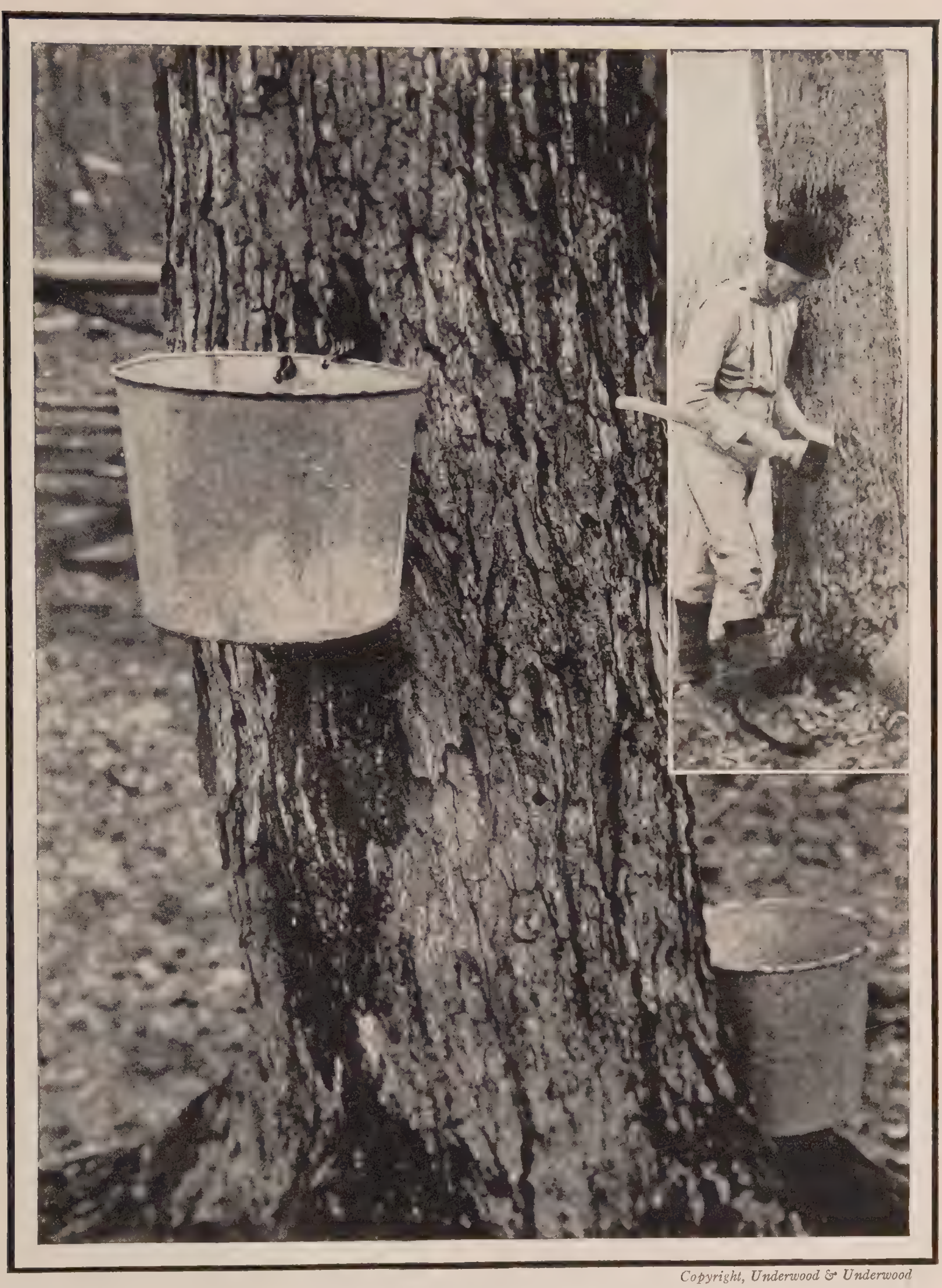
The bees are easily handled at swarming time. They are good-natured and seem to look on the experience as a sort of holiday lark. Moreover, they will have filled themselves with honey just before leaving the hive, and in that condition cannot easily bend their bodies to sting. It is necessary to hive a swarm of bees within a short time after they take their departure, for otherwise they will sail into the air again and perhaps travel several miles to the new home selected by the scouts.

THE HONEY INDUSTRY

In ancient days honey was the only form of sugar known, and it was highly prized. From the Hebrews' use of the phrase, "flowing with milk and honey," to describe fertile lands where food was plentiful, we know that they considered honey a symbol of abundance. Not only was it important as a food, but also because of its use in medicinal compounds and its place in religious rituals.

To-day honey forms a very small part of the sugar consumed in the world; yet the amount produced is sufficient to make beekeeping an important industry. The United States is the leading honey-producing nation in the world, with a season's output which often runs as high as 25,000,000 pounds. Canada's production is figured in millions of pounds also. Thousands of pounds of honey are imported by the United States from Cuba, Mexico, and South American countries, while from Greece, Syria, and Russia come smaller amounts. There is hardly a country in the world where honey is not produced.

BEES LIVING ON COMBS BUILT IN THE OPEN AIR



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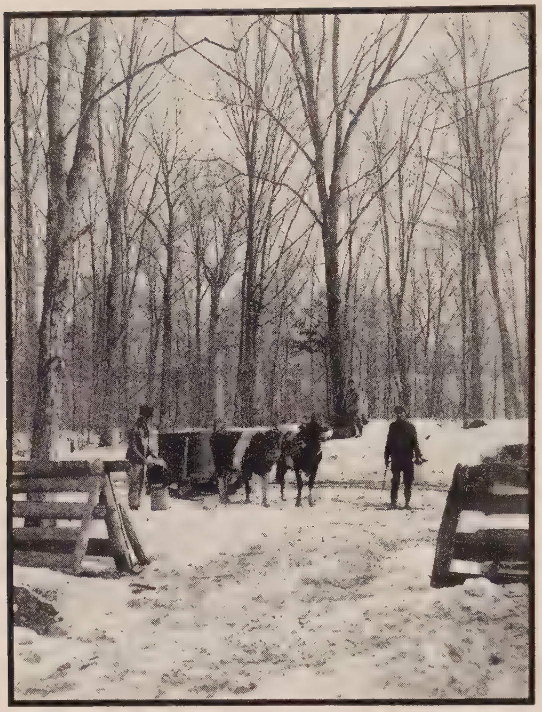
TAPPING A MAPLE TREE AND GATHERING SAP FOR SUGAR OR SYRUP

The pioneers of New England and Canada made maple sugar, learning how to tap the trees from the Indians, who had a time on their spring calendar named for the "sugar-making moon."



COLLECTING SAP

In some places an ox-team is still used to carry sap to the sugar house.

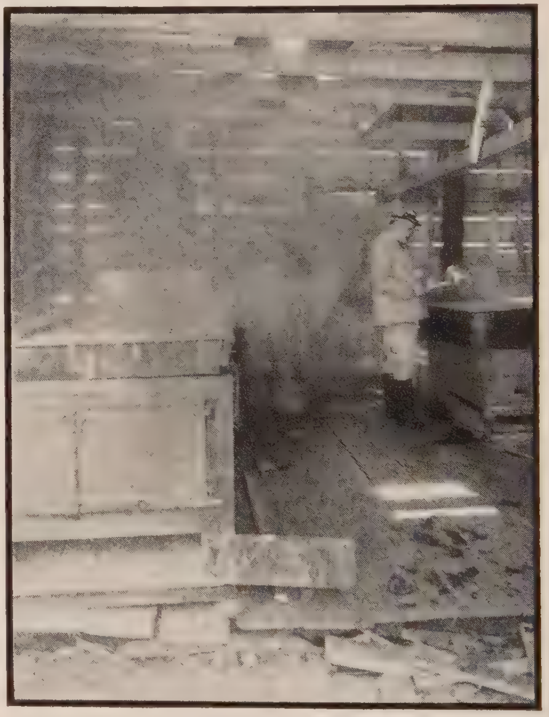
MAPLE SUGAR

THE art of making sugar from the sap of the sugar maple, which grows in the northeastern part of the United States, was taught to the early settlers by the Indians. Very welcome was this contribution of sugar to the scanty supply of available provisions, and it was thought that maple-sugar making might become of tremendous importance commercially. However, the sugar has proved to be a luxury rather than a staple, and the industry is carried on chiefly in Vermont, New York, and Ohio. These three states produce about three quarters of the total amount for the whole United States. Canada produces about the same amount of maple-sugar and syrup as does the United States.

In the olden days maple-sugar making was a most picturesque process. Each farm made its own sugar and syrup, by boiling down the sap over open fires, or a little later, in crude evaporating pans in rough sugar houses. Now it has become more of a factory industry, with modern equipment which prevents deterioration and turns out a more uniform, dependable product.

It is when winter is breaking up, bringing thawing days and freezing nights, that the sap begins to run. The flow continues until the trees begin to bud. There are three or four different runs, of which the first gives the largest percentage of sugar.

To procure the sap the trees are tapped; that is, small holes one to two inches long are bored in them at a height of about three feet from the ground. A spout is driven in each hole and a bucket hung on the spout. As the buckets are filled, the sap is collected and transported to the sugar house. In large sugar groves, in order to save time and labor, the sap is piped to the central collecting point. For the finest-flavored sugar, the sap must be immediately evaporated by means of heat until the desired consistency is obtained. Some of the syrup is made into sugar by being stirred until it crystallizes, but 90 per cent of it is marketed in liquid form.



IN A SUGAR HOUSE

At the left is the "evaporating pan" in which maple sap is cooked down to syrup and sugar.

Courtesy of Food Industries

PACKING CHOCOLATES

The speed with which these girls remove the candy from the conveyor on which it passes before them and pack it in boxes, is amazing.

CANDY MAKING AS AN INDUSTRY

A GOODLY proportion of the annual sugar crop goes into the hands of commercial candy makers, who add nuts and fruits, flavoring extracts and coloring matter, and turn out the attractive confections which tempt Americans into being the candy eaters of the world. Hundreds of tons of candy are consumed in the United States daily; if the whole amount eaten in a year were divided equally among all the people in the country, each one would have about sixteen pounds. The money spent by Americans for candy each year is more than $500,000,000.

The tremendous output is made possible by the machines which have been invented to do the work of dozens of men. In some of the smaller factories which produce the so-called "homemade" candies, some hand work is retained, but in the larger plants almost every step is carried through by machinery.

The foundation of the great majority of candies is a sugar syrup. This is prepared by cooking sugar and water together in huge kettles. From these kettles the syrup is piped into the various departments where different types of candy are made. The syrup, with other ingredients added as specified by the recipe, or formula, is again cooked in big steam kettles until the desired temperature is registered on the thermometer with which it is tested. For fondant, which is the basis of all cream candies, the syrup is stirred until it thickens and forms tiny crystals.

The molding of fondant into centers for chocolates is one of the most interesting processes of candy making. First, large wooden trays are filled with cornstarch, which is shaken down and leveled off in a machine. Then, also by machine, plaster of Paris molds are pressed down into the starch, leaving long rows of clearly defined impressions. The trays then pass along to a machine which pours into each mold a measured amount of the fondant which has been softened by heat until it is semiliquid. If nuts or fruit are used, they are deposited in the molds by another part of this elaborate mechanism. When the centers have cooled and hardened, they are emptied from the tray and freed from starch. They are now much harder than the cream centers which we are accustomed to find in our chocolates, but they will mellow and soften after they have been coated. The starch, cleaned and resifted, is used over and over again.

For candies like fudges and caramels which are to be cut in squares, the mixture is poured out, while it is still soft, onto a big metal-covered table and shaped by steel bars into a huge rectangle.

The finest chocolates are still hand-dipped; that is, each center is taken separately by a worker and dipped into a mass of softened chocolate which she has before her. This method gives a heavy coating, and is distinguished by the curlicue of chocolate formed on each candy. Machine dipping is far more common than hand dipping at present, however. The centers, on a strip of wire netting, pass through a machine where melted chocolate is forced up from below and poured down from above, so that the entire candy is coated. The room where chocolate dipping is done is kept at a constant temperature, cooler than the ordinary room, for too much heat causes chocolate to show gray spots as it hardens.

The making of some of the hard candies is a fascinating procedure to watch, for it involves skillful hand work. The syrup, which has been cooked to a high temperature, is poured out onto metal-topped tables. As it starts to harden it is worked gently by men wearing heavy leather gloves to keep it in a mass of uniform consistency. If filled candies, like the popular "peach blossoms" or soft-centered fruit drops are to be made, the filling is placed in the center of the mass, after it has been flattened out a little, and the edges are folded over, just as dough is folded over the apples in a dumpling. At the proper moment the candy is brought to a "batch warmer," a steam-heated table at one end of which is a gas burner several feet long with a rounded trough before it. In this trough the candy is shaped, being gradually pulled out into a slim roll; then it passes through a cutting machine which quickly divides it into individual pieces. A batch of candy which is handled in this way may weigh as much as 75 pounds.

The hard candy wafers that we buy in rolls are made from an uncooked mixture consisting chiefly of pulverized sugar, with gum arabic to give the necessary body. This is flavored and colored. The ingredients are kneaded together in a mixing machine, then rolled thin, and shaped by a cutter which makes hundreds of the little discs at one time. Before the candy is ready to pack, it is taken on long conveying belts to heated rooms where it dries and hardens.

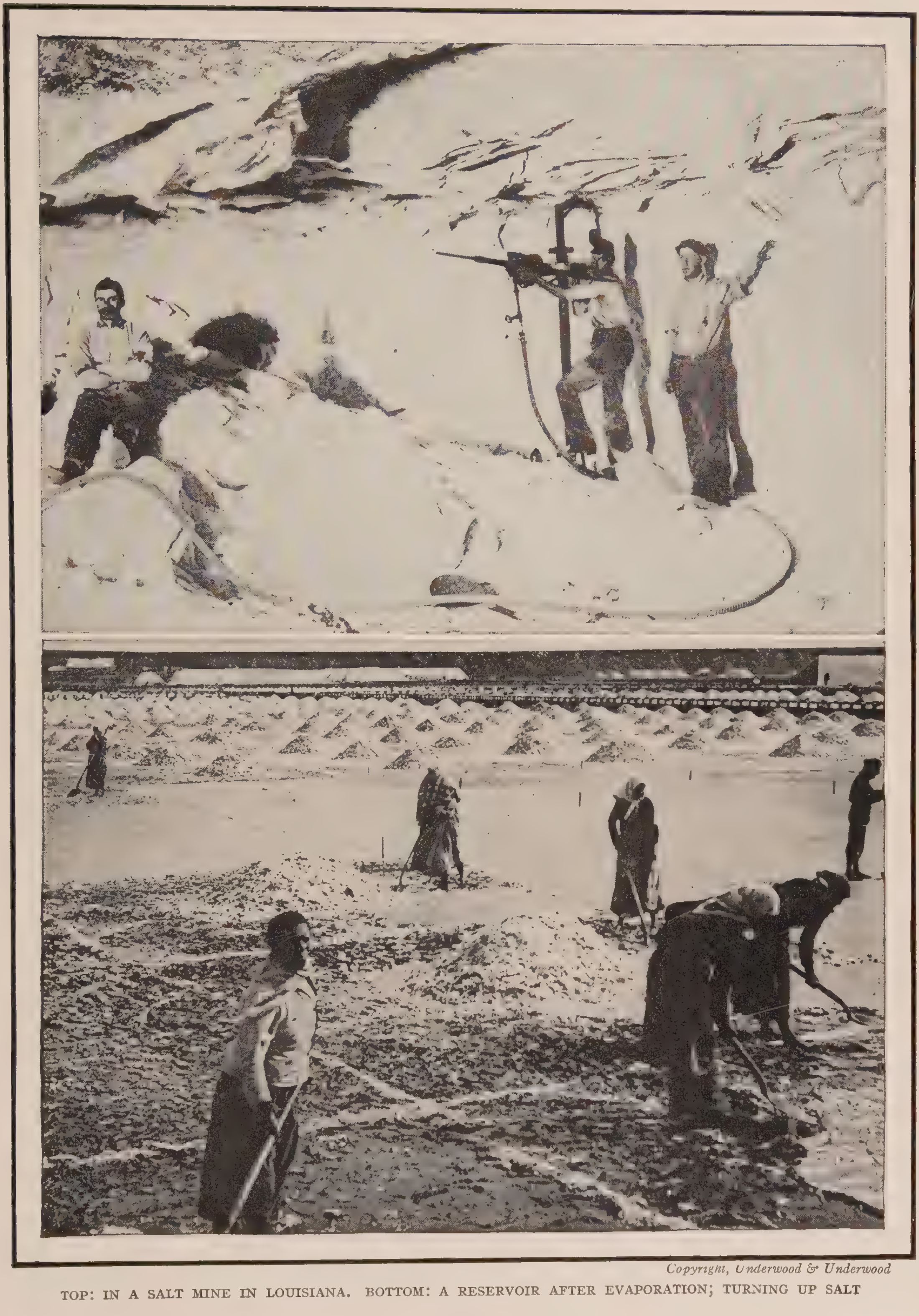
It is said that we owe our start in commercial candy making to a French nobleman, the Count of Singeron. Exiled from France at the time of the Revolution, he fled to New York, where he took up the occupation of frosting and decorating cakes and making the bonbons for which France was famous. Switzerland gave us the chocolate bar and the nougat, Turkey the fruit paste. We have taken all these kinds and made them our own, building from them and elaborating upon them until we now produce hundreds of different varieties.

SALT

SALT is such a common and necessary product that it is used by everyone. You know how tasteless food is if there is not enough salt put in to flavor it. Perhaps the best definition of it is that of the schoolboy's composition: "Salt is what makes potatoes taste bad when you don't put any on." Very likely we do not realize that no living thing can exist without a certain number of these simple white crystals being carried into the system and into the blood.

Animals are quite as dependent on salt as is man, and doubtless you have seen farmers giving it to their cattle and sheep. Shepherds often call their scattered flocks together by making a sound which the creatures have come to understand means *salt;* the sheep themselves, too, give a peculiar call to summon each other when they find this substance in the soil of their pastures. Centuries ago one method of torturing criminals was to put no salt in their food and give them nothing but flat rain water to drink. Under this treatment they soon died.

And yet it is a curious fact that while a certain amount of salt is necessary to all life, too much of it is fatal. Nothing can grow where there is an abundance of salt; and this is the reason why salt is used to preserve meat, fish, and other kinds of food. No germs can thrive when products are packed in it. Fishermen who go on long cruises always carry with them a supply of salt, and as fast as they catch their fish they clean them and salt them down for market.



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TOP: IN A SALT MINE IN LOUISIANA. BOTTOM: A RESERVOIR AFTER EVAPORATION; TURNING UP SALT

WHAT IS SALT AND WHERE DO WE GET IT?

Salt is made up of two elements: sodium and chlorine. Sodium, by itself, is a soft metal easily cut with a knife; chlorine is a dangerous gas which can kill if much of it is breathed into the lungs. When these two very unlike elements combine chemically they form sodium chloride, or common salt. However, it is not necessary for us to combine these two elements in order to get salt, as great quantities of salt exist in the sea and in the earth.

The earliest way of getting salt was to take it from the sea by scooping shallow holes along the seashore into which the breaking waves would throw salt water. Then, with no chance to drain back, the salt water, or brine, as it will hereafter be called, would be dried up by the sun, leaving deposits of crude salt on the sand.

The first actual refining of salt was done on the shores of the Dead Sea, where the coarse salt mixed with sand was placed in a stone vessel of water and dissolved into brine again. After the sand had sunk to the bottom the brine was run into shallow stone troughs and exposed to the sun's rays until the water disappeared, leaving a rough but fairly pure salt. Salt is still made from sea or salt lake water in China, France, Portugal, Spain, Italy, Central and South America, the West Indies and, to some extent, in the United States. In the picture on page 141 of Volume One, you can see salt heaps on the shore of the Great Salt Lake in Utah.

A second way is to mine rock salt from the earth. Salt is found in almost every part of the world. Occasionally salt deposits or veins occur near the surface of the earth, and mines in such locations are merely shallow pits from which the salt is dug. In most cases, though, rock salt lies far beneath the surface and shafts are sunk and working galleries are run off them just as in a coal mine. Rock salt has been mined since about the year 1000 A.D. The oldest known mine, the famous Wieliczka salt mine in Poland, dates from about that time.

The third and most modern way, is that of the salt well. A well is drilled down to the rock salt deposit in much the same way as a water, gas or oil well, except that it has a double casing or pipe—one inside the other. Pure, fresh water is pumped down the outer casing to the salt vein below and forms a brine which is forced up the inner casing by the pressure of the fresh water coming down. As the brine comes into the refinery from the wells it goes first to great settling tanks, where it stands until any non-dissolvable matter which has come up from the well has settled to the bottom. Then the clear brine goes into a second series of open tanks, heated with steam coils, where a special chemical treatment is given it to remove any impurities it may still contain. The brine is now sparklingly clear and entirely free from impurities, consequently the next operation is to change it into salt by a process of evaporation.

The evaporators are long shallow pans heated by steam coils. They range in length from 90 to 120 feet, are from 12 to 15 feet in width, and are uniformly 2 feet deep. As the brine becomes hot the water it contains turns into steam and passes off. Meanwhile the salt crystals form on the surface of the brine, float for a few minutes, and then sink gently to the bottom. The size of the grains of salt is determined by the degree of heat used, low temperatures producing coarse crystals and high temperatures fine ones. Toward the bottom of the evaporators are automatic rakes which slowly push the salt crystals to the end of the pan and up an inclined drain board. There they fall onto a moving belt which whisks them away to the dryers.

Newly-made salt comes from the evaporators in a very wet condition indeed. Small drops of brine still cling to the crystals, and the whole mass has a slushy appearance. Therefore it goes first to a series of filters which reduce the amount of moisture in the salt to about 2%. From there it proceeds to a rotary dryer, a revolving steel cylinder lined with rust-proof metal, which is heated to a very high temperature throughout its entire length.

After the salt has passed from one end of the rotary dryer to the other it runs like hot sand, and is ready to be separated into crystals of various sizes. This is accomplished by sifting it through automatic shaking screens.

Finally the salt is weighed and packed in bags or other containers and comes to us ready for use. It is said that salt has over 1400 different uses, ranging from the seasoning and preserving of our foods to the melting of ice on our sidewalks.

SPICES

OF all the food products which supply our everyday needs, spices have the most interesting and romantic history. They were known in earliest times, and because they were rare and obtained with great difficulty, they were valued with gold and precious stones. Spices were a symbol of luxury, for only the rich could afford them. They were offered as tribute to kings and emperors, and were used in the highest religious ceremonies. It was in the hope of finding a short passage to the Far East, from which spices and other treasures came, that Columbus undertook the voyage that brought him to America, and that the passage around Cape Horn was discovered. Later, in the attempt of one country or another to gain a monopoly of the spice trade, battles were fought and blood was shed.

No longer is spice such a rarity. Scientific cultivation produces spices in abundance, and modern methods of transportation bring them to us regularly, so that our grocers' shelves are well supplied with all varieties, and we are able to purchase them at low cost.

THE NATURE OF SPICE

A spice is not a food in the sense of supplying nourishment to our bodies, but a condiment, a food adjunct which we value for variety and flavor.

All spices are aromatic or pungent vegetable substances, produced from different parts of plants. Cinnamon, for instance, comes from the bark of a tree; cloves are flower buds; allspice is a fruit; nutmeg, part of a seed; ginger the rootstock of a plant. Herbs, such as thyme, bay leaf, sage, marjoram, and mint, which are considered in the same food class as spices, are the upper portions of plants.

Spices are grown, for the most part, in the tropical countries of the Eastern Hemisphere, on the islands of the Malay Archipelago, in India, China, and the West Indies.

A complete list of the spices which the market offers is a long one, but only a few varieties are in common use. Pepper, cinnamon, cloves, allspice, ginger, nutmeg, mace, and mustard are the kinds we know best.

PEPPER

Pepper, which is the most used of all the spices, is of two distinct types. Black pepper and white pepper come from the same source, the fruit of the *Piper Nigrum*, a perennial shrub which climbs on the trunks of trees. It is native to the Malabar coast of India, but now grows in other Eastern countries.

The pepper berries grow in clusters or spikes. Sometimes as many as thirty berries are found on a single stem. To make black pepper, the berries are picked before they are fully ripe, and dried in the sun or over slow fires. These whole dried pepper berries are familiar to us as peppercorns. The very finest white pepper is obtained from berries which have been allowed to ripen on the vines; but since this practice is injurious to the plant, the product is more often prepared by removing the outer shells of the unripe berries. Black pepper has more strength and pungency than white.

The red peppers come from *Capsicum*, a plant which bears no relation to the pepper vine. Japan, India, Africa, Zanzibar produce large quantities of red pepper, and we also have a supply from the state of Louisiana. The fruit is pod-like, consisting of an envelope of flesh, within which are spongy pulp and seeds. Cayennes and other "hot" red peppers are made from the dried ripe pods, including both flesh and seeds. Paprika, which is pungent but not hot, is prepared from the flesh only of the common capsicum, a variety cultivated chiefly in Hungary and Spain.

CINNAMON

True cinnamon comes from the Ceylon cinnamon tree of the island of Ceylon. Cassia, which in ordinary use we do not distinguish from real cinnamon, is the inner bark of the cassia cinnamon tree of China, Japan, and India.

The cinnamon tree is much like our willow in its growth. To obtain the spice, shoots are cut when about an inch thick, and the bark is stripped off, tied in bundles, and allowed to ferment. Then the outer skin is removed, and the inner portion dried in the sun, curling during the process into the familiar quills of stick cinnamon.

CLOVES

The clove tree is an evergreen of the myrtle family, native to the Molucca Islands, but now growing on many other islands of the East and West Indies. When the flower buds turn a dull-red color they are gathered. This is a tedious process, for care must be taken not to damage the tree and so prevent further development.

After the picking, the cloves are spread out on mats to dry. During this process they shrink and turn to the brownish color, by which we know them.

NUTMEG AND MACE

Our nutmeg is the kernel of the seed or stone of the nutmeg fruit. Mace, which is similar in flavor, is the fibrous covering of the stone. The nutmeg tree bears constantly, so that blossoms and ripe fruit are often seen together on one tree. As the fruit matures it is picked, the flesh stripped off, and the mace separated from the stone. The pits are dried until the kernels rattle; then the shells are cracked and removed. The mace is flattened out and placed on mats or trays, to be dried either in the sun or by artificial heat. During this curing process it turns from crimson to a yellowish or golden-brown color, and becomes wax-like in appearance.

ALLSPICE

Allspice is not, as many people think, a mixture of spices, but a distinct variety in itself. It is the fruit of the pimento tree, an evergreen which, like the clove tree, belongs to the myrtle family. It originated in the West Indies and is now found also in Mexico, Costa Rica, and Venezuela. The berries are picked just before they become fully ripe and are cured by drying in the sun. These dried berries are very similar in appearance to the peppercorn. From this fact they take their name, *pimento*, which is the Spanish word for pepper. The more common name, allspice, has been given because in flavor the spice suggests a combination of nutmegs, cloves, and cinnamon.

GINGER

Ginger is a perennial reed-like plant which flourishes in China, Japan, Africa, and other tropical and semi-tropical countries. The finest variety grows in Jamaica. The root is the spice-yielding part of the plant. It is prepared, before drying, either by scalding or by scraping and washing. The latter method produces the so-called white ginger.

MUSTARD

Mustard, one of our commonest spices, is prepared from the seeds of an herb. The mustard plant is familiar in our own country, and grows in the temperate zones of many other lands. The process of making mustard flour, or ground mustard, is very similar to that of preparing wheat flour. The seeds are cleaned; the inner portion is separated from the husks; and the meat is ground fine. There are two types of mustard: brown, or black, as it is sometimes called, which is very strong in flavor; and yellow, or white, which is milder. To give the best results, the two are commonly blended.

OUR SPICE INDUSTRY

The work of drying spices and preparing them for shipment is done by the natives of the countries in which they are raised. At the mills in this country they are given whatever sorting and cleaning is necessary, and the greater percentage is ground. As in other branches of industry, methods have been improved and special machinery developed until to-day the processes of milling and packaging spices are carried on with remarkable speed and efficiency.

When we consider the small amount of spice that is needed to season any one dish, it seems hardly possible that the spice industry can be of importance; but if we count up all the cookies and cakes, pies and puddings, desserts and confections that owe their savor to a dash of spice, it is not so surprising to learn that between five million and seven million dollars worth of spices are brought every year into this country alone.

Courtesy of California Dried Fruit Research Institute

PRESERVING FRUIT BY NATURE'S OWN METHOD

In a few days the heat from the summer sun will have changed these bunches of grapes spread on trays into raisins.

FOOD PRESERVATION

ONE of man's earliest problems was that of food preservation. The meats and fish and fruits and vegetables which Nature provided for his needs were, he found, exceedingly perishable. After they had been kept a short time they were no longer appetizing, and to eat them caused illness. Yet it was impossible to have an abundance of fresh food every day, for fish and game were not always plentiful, and it was only at certain seasons that plants bore fruit.

Fortunately for us, the problem has been solved. Modern methods of food preservation make it possible for the whole civilized world to have food in abundance and in great variety. It is hard for us to imagine how different conditions would be if this were not the case. Without efficient means of preserving food, each little community would have to depend on what it could raise, for transportation over long distances would be out of the question. Great cities could never have come into existence, because the surrounding area could not produce sufficient food to supply the thousands of people. There would be seasons of abundance, with appalling waste of surplus food, and seasons of famine. Variety would be greatly limited, and we should have to forego many of the delicious foods which we now so greatly enjoy.

EARLY ATTEMPTS AT FOOD PRESERVATION

One of the first preservatives with which man experimented was salt. Meat and fish, he found, could be kept a long time after treatment with this substance, and salt was therefore highly prized. Smoking was often used to improve still further the keeping qualities of meats and fish. To-day the processes of salting and smoking are still used, but perhaps more for flavor than for preservative effect; and the scientific procedure followed produces results which are very different, we feel sure, from those which our remote ancestors obtained.

In early times spices, too, were considered of great value for their preservative properties. The truth is, however, that in many instances the spices served to disguise the unpleasant flavor of spoiled food rather than to keep it sweet and fresh. Spices in moderate amounts have practically no preservative effect.

DRYING

Drying has been called Nature's own method of preservation. It was recognized and utilized in very early times, and it is so effective that it has persisted to the present day. In hot, dry countries, where moisture is quickly absorbed by the air, hunters and fishers early learned to dry the meat and fish which they caught, and householders discovered that fruits, if they were dried, could be enjoyed long after the harvest season was past.

The American Indians used to cut their buffalo meat in thin slices and dry it in the sun or over a fire. Then they would pound it to a powder and pack it into buffalo-skin bags with alternate layers of fat. Pemmican, a food which has long been the mainstay of the explorer's ration, is an adaptation of this product. Pemmican is a mixture of dried meat and fat, with dried fruit added to give better nutritive balance. It is a very concentrated food, which will keep indefinitely and is easily carried.

Dried vegetables, such as carrots, celery, onions, and spinach have long been known and are still marketed to some extent, but the demand for them is not great. Beans and peas are the only dried vegetables of importance at present. A vegetable flour is a recently developed dried-vegetable product which has created considerable interest. It is made by a special process which retains the nutritive properties of the fresh vegetables, and is therefore important in the light of present-day nutritional studies. The vegetable flours are quite different in their properties and reactions from flours made from grain, but they have many uses in cookery.

Dried foods, besides having excellent keeping qualities, can be easily handled and cheaply transported. They are not susceptible to temperature changes, as are fresh foods, they occupy relatively little space and are light in weight. The reason why drying is not a still more widely used method of food preservation is that it changes the texture and flavor of the foods. When we remember, however, the dried milk and dried fruits which were discussed in this volume (pages 332-334) as well as the products just mentioned, we realize that quite a large portion of a year's crops is preserved by this method.

COLD AS A PRESERVATIVE

The fact that cold prevents spoilage of food was recognized long before it was understood. From the records of very early times we learn of man's efforts to produce artificial cold in warm countries where natural temperatures made food preservation a particularly difficult problem.

Hundreds of years ago the Egyptians discovered that ice could be made in the open air in hot weather by a simple method depending for its success on the heat of the sun and the dryness of the atmosphere. They would scoop out a hollow in the earth and line it with rice straw. A very shallow earthenware vessel was placed in the hollow on the straw, which, because it is a poor conductor of heat, gave protection from the warmth of the earth. Water was then poured into the vessel. The hot, dry air above it rapidly absorbed the surface water, or caused it to "evaporate." This evaporation produced such a degree of cold that very thin flakes of ice formed around the edges of the vessel. These were collected with much care and used in the goblets of wine served to the kings. Other foods were cooled by being placed in the cold water.

When Nero came into power in Rome he introduced a refrigerating scheme which was carried out with tremendous expenditure of human energy. From high places in the Apennine Mountains the emperor's slaves were forced to carry quantities of snow. This snow was stored in deep trenches and covered with sod and straw. Thus protected from the heat of the air, it would keep for weeks, to be used as needed for cooling the wines, fruits, and fish for royal feasts.

AN IMPORTANT DISCOVERY

For hundreds of years there was little real advance in methods of food preservation. It was not until the invention of the microscope in the latter part of the seventeenth century that a turning point came. Through the microscope the existence of countless millions of tiny organisms, heretofore invisible, became known. When Anton Van Leeuenhock, a Dutchman who made the first microscope, began telling about these microbes he was ridiculed and declared mad, but before long he was able to prove that he was right. At his death his work was continued by other scientists.

As the micro-organisms, which we now know as bacteria, yeasts, and molds, were studied, a new light was thrown on the problem of food spoilage. It became evident that these minute organisms were responsible for the changes that made food unfit to eat. The discovery that germs could be killed by heat led scientists to investigate also the effect of cold upon micro-organisms, and it was soon proved that low temperatures retarded their growth and, for this reason, helped to prevent food spoilage.

THE DEVELOPMENT OF REFRIGERATION

In the year 1799 ice was first harvested in America. This was cut at the foot of Canal Street in New York City. A few years later we have the first record of delivery of ice to an American home. During the nineteenth century the harvesting of ice became an industry of importance. Cold storage warehouses for holding foodstuffs at the distributing centers were established, refrigerator cars were built, and household refrigerators became common.

But natural ice is a product of cold weather. Obviously, then, it is not available everywhere and at all seasons. It is a heavy substance, expensive to ship, and to the actual cost of transportation must be added a high percentage of loss by melting. Except in climates where winter produces a dependable supply of ice, it is not practical for the refrigeration of great warehouses such as our modern system of food distribution demands, and it is even too expensive for use in the average family.

Here the scientific inventor has come to our rescue. Following the ancient art practised by the slaves of the Pharaohs, he has made ice at will and produced refrigeration entirely independent of natural temperatures. He has learned methods far more effective than those of the first ice makers; he has used substances other than water, and means other than direct evaporation in the air; but the underlying principles are the same as those employed hundreds of years ago.

PRINCIPLES OF MECHANICAL REFRIGERATION

Mechanical refrigeration is made possible by the fact that certain substances exist in three different forms — solid, liquid, and gaseous — and change from one to the other by the application or withdrawal of heat. Water is an example with which we are all familiar. We know that ice, a solid, and steam or water vapor, a gas, are both forms of water. Experience has taught us that ice plus heat equals water, and that water plus heat equals steam. We have observed also that, conversely, when steam cools it forms water again, and when enough heat is taken away from water it freezes or becomes ice.

The snow which cooled Nero's wines did so by utilizing the heat that was in these wines as it turned to water. In the case of the Egyptians' evaporation method of producing cold, the heat of the water left in the vessel was removed by that which evaporated, for evaporation (which is the name of the process by which a liquid is changed into a gas) is accompanied always by the withdrawal of heat from some source.

Every liquid, exposed to the air, evaporates in small amounts. At a specific temperature it evaporates violently, changing suddenly from a liquid to a gas. This temperature is called the boiling point. At this point the liquid will absorb a great many heat units without changing its temperature; all the heat is utilized in the transformation from one state to the other. Water, for instance, boils at 212° Fahrenheit. When a pound of water at 212° changes to steam at 212°, 970 heat units are required, whereas a single unit of heat will raise that same amount of water from 211° to 212°.

For efficient refrigeration a substance which boils or vaporizes at a low temperature is chosen. Ammonia with a boiling point of about −33° F. is the refrigerant most widely used commercially. For household refrigeration sulphur dioxide which boils at 14° F. is commonly employed. Other refrigerants are ethyl chloride, methyl chloride, and carbon dioxide.

The change from gaseous to liquid state may be accomplished by pressure as well as by removal of heat. The molecules of which a gas is composed are not in so close contact as when the substance exists in liquid form; that is, expansion takes place in vaporization. If the gas is squeezed into smaller volume by application of pressure, the molecules are forced together until they form a liquid again. This characteristic of the refrigerant is also considered in mechanical refrigeration.

Another scientific principle which enters into refrigeration is the tendency of heat to pass from a warmer to a colder place, just as water flows from a higher to a lower level.

With these facts in mind it is not difficult to follow the "refrigeration cycle," the course of operations which take place when a refrigerating machine is in action.

THE REFRIGERATION CYCLE

Let us take as an example an ammonia compression machine. First, the refrigerant, in the form of a gas, is compressed in an electrically operated compressor. It is still a vapor when it leaves this machine, but is just on the point of becoming a liquid. It is liquefied as it passes into a coil of pipe surrounded by cold water. Next it passes through a small opening which releases the pressure. It is at this point that refrigeration takes place, for, as the pressure is released, the liquid takes up heat from whatever is nearest it, and expands into a gas. The ammonia is now back again in its original condition and is ready to be compressed again. Whatever the refrigerant used, these processes of compression and expansion are carried on in much the same way.

TYPES OF REFRIGERATING MACHINE

The compression machine just described is the type most extensively used to-day. A second type is the absorption machine, in which, strangely enough, heat is the essential factor. In the absorption method the refrigerant, usually ammonia, is absorbed by water. By the heating of the mixture of ammonia and water the ammonia vapor is driven off and condensed to a liquid under pressure. The pressure is now reduced; and as the liquid comes in contact with the substance to be cooled, it absorbs heat from that substance. In so doing it becomes again a vapor. Meanwhile the water is cooled and is ready to reabsorb the ammonia vapor. The household refrigerators which are operated by gas are of the absorption type.

The low temperatures obtained by such a machine may be used in various ways. Pipes containing the ammonia may be located around the walls of the refrigerator or cooling room. This is called "direct cooling." The ammonia pipes may pass through a tank containing salt water or brine, which will remain a liquid at very low temperatures, and this may be circulated by a pump through pipes around the refrigerating room. This is "indirect cooling." Or, again, the ammonia may be circulated in such a way that water may be made into ice.

An important advantage of artificial refrigeration is that much lower temperatures can be obtained than with ice. Ice alone can cool the space about it to a temperature no lower than its own, 32° Fahrenheit. Under ordinary conditions, the temperatures in an ice-refrigeration system will be far above that point. The smaller the proportion of ice to storage space, the higher will be the temperature. Since 50° is the point above which bacterial life becomes active, refrigerators and storage plants must always be kept cooler than that. For preserving food over long periods, temperatures very much lower are essential. By means of mechanical refrigeration, adjustments can be made to give the temperature best adapted to the type of food under consideration.

COLD STORAGE

The most important application of refrigeration is in our modern cold storage system. Cold storage plants, together with the refrigeration service offered by railroads and steamships, influence the life and economic condition of the entire civilized world. It is cold storage that prevents waste of perishable food products which cannot be disposed of as rapidly as they reach the marketable stage. Cold storage provides adequate food for the thousands of people who live in crowded cities; it makes possible interchanges of food between different sections of a country and between different countries, thus equalizing to a great extent the food distribution throughout the world. Finally, it provides us with delicacies from far countries, and caters to our taste for out-of-season luxuries.

Every large city has its cold storage warehouse, containing acres of floor space and capable of taking care of tremendous quantities of perishable foods. Meat, fish, poultry, eggs, butter, fruit, and vegetables will all be found in such a storage center.

Ice is a possible refrigerant for smaller warehouses, but the larger plants could not function efficiently without artificial refrigeration. The ammonia compression system with the indirect method of cooling is most widely used. The operation of the machine chills a brine which can be reduced to a very low temperature without freezing. The brine is circulated through a system of pipes to the various storage rooms, where it takes up heat; then it is returned to the machine to be chilled, and is used over and over again. The temperature can be adjusted so as to give the degree of temperature required for different types of storage. Proper ventilation is provided in the storage rooms, and various means used to keep the air pure and odorless.

Refrigerator cars are an important factor of our cold storage system; for they bring foods in good condition to the cold storage plant and deliver them wherever they are needed when taken from storage.

These cars are like ordinary box cars in appearance, but are constructed with insulated walls to prevent entrance of heat. Some, like cold-storage warehouses, are cooled by circulation of chilled brine, but ice, or a combination of ice and salt, is still most commonly used. Compartments for ice are located at the ends of the cars or in the center just under the roof. The ice is replenished as necessary to keep low temperatures during the trip. Special refrigerator cars for milk consist of two huge glass tanks, each of which holds hundreds of gallons. These tanks are surrounded by ice.

Refrigeration on shipboard is the final link in the chain of fresh food distribution over all the world.

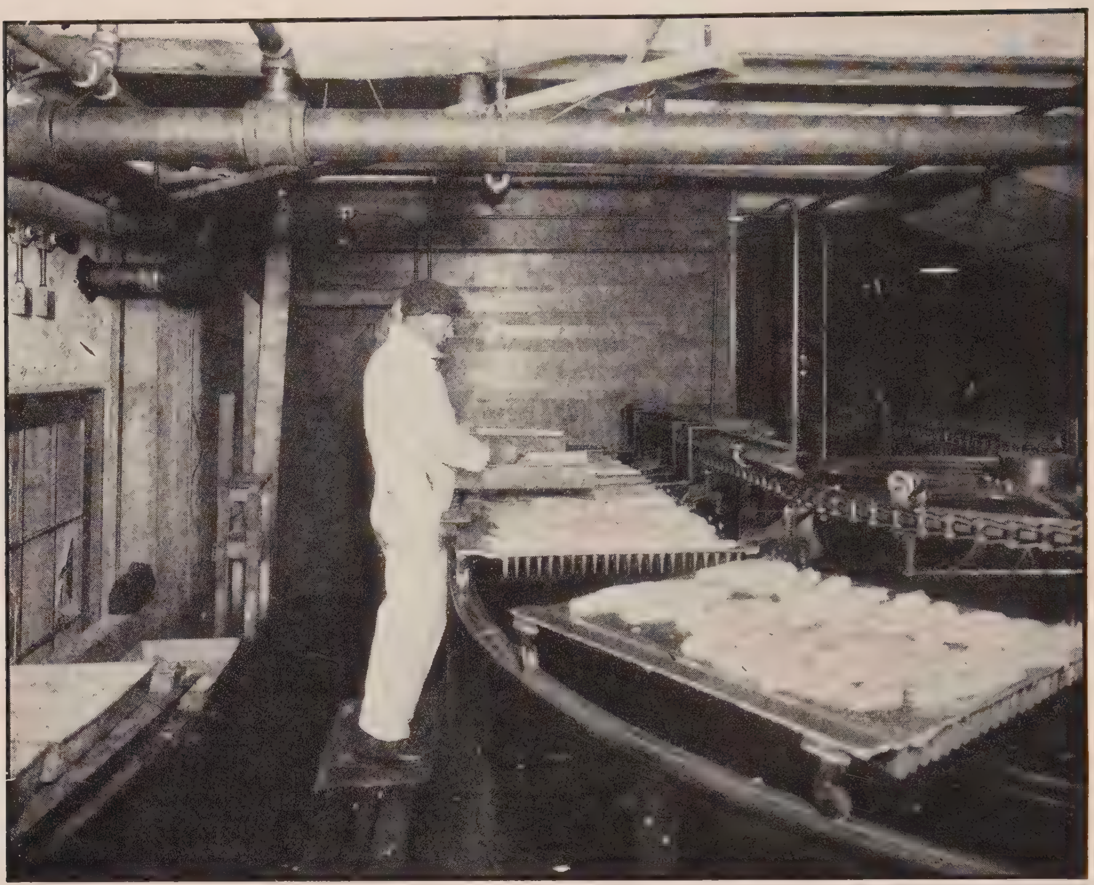
OTHER USES OF ARTIFICIAL COLD

Ice-making plants are extensively used, especially in those climates where natural ice cannot be produced. Artificial ice is made in two ways, by freezing water placed in cans so that each can will contain a 200- or 300-pound cake of ice, or by immersing metal plates in a tank of water and causing ice to form on these plates in large cakes. Artificial ice is much purer than that frozen naturally, for it is made from distilled water.

Artificial household refrigeration is finding wide application throughout all sections of the country. Many large apartment houses are now equipped with a single system which supplies artificial cooling to the refrigerator of each apartment in much the same way that is used in the commercial warehouses. Small domestic machines are being rapidly introduced into private residences, and development along the line of moderate cost with increased efficiency is continuously proceeding. These small machines are so completely automatic that they require little or no attention.

ARTIFICIAL COLD FOR COMFORT AND PLEASURE

Refrigerating plants for cooling the air through the hot season have been installed



Courtesy of Food Industries

FILLETS OF FISH READY FOR QUICK FREEZING

As the aluminum plates on which the fish is spread pass along through the freezing room, they are brought in contact with very cold brine. When they come out, the fish is thoroughly frozen.

in many public offices, auditoriums, theaters, department stores, and in many factories where it is important that the product be kept at an even temperature regardless of the season of the year, as well as in private houses of wealth.

Artificial ice machines are also used to produce ice for skating rinks. A large floor is covered with a network of pipes through which the chilled brine flows. This floor is then sprayed with water in a fine shower, by an ordinary garden hose, and the tiny drops freeze almost as soon as they touch it. When a sufficient thickness is reached, a very perfect surface for skating is produced. In this way ice skating may be indulged in within the torrid zone during the warmest season.

FROZEN FOODS

As we trace the development of artificial refrigeration still farther we come to the actual freezing of foods. For many years frozen fish and meat have been sold in our markets, but we have not had much confidence in their quality. They were likely to be inferior products, lacking in flavor, spongy in texture, and altogether far less desirable than fresh foods.

But by the modern method of freezing, the original properties of the foods are retained, so that we now have frozen meats which, after cooking, cannot be distinguished from fresh cuts, fish which taste like those straight from the sea, and fruits and vegetables as delicious as if they had just come from the garden.

To explain why quick freezing is so much more satisfactory than the old slow-freezing process, we should have to go far into the fields of chemistry and bacteriology, and even there we should not find answers to all our questions, for scientists are still puzzling over the facts. Experience has shown, however, that by rapid freezing the food cells do not deteriorate as they do when frozen slowly. So, when the material is thawed, it is practically identical with the strictly fresh product.

METHODS OF QUICK FREEZING

The different methods of rapid freezing which are at present in use come under two general heads, direct contact and indirect contact.

By the direct-contact method, the material to be frozen is dipped in or sprayed with brine which has been mechanically cooled to a very low temperature. This is the most rapid of all the processes, but it presents a number of difficulties. It is suitable only for meats and fish, and has an undesirable effect on the surface of the products.

There are various applications of the indirect contact process. The material to be frozen may be packed in cans or waterproof bags and immersed in or sprayed with brine, after which it is removed from the cans and packaged for distribution. Or it may be placed in a shallow layer in large pans and floated on a stream of brine until frozen. Another process makes use of brine-cooled metal plates on which the material is placed. The "double contact" procedure makes use of two refrigerated metal belts, between which packages of food travel and are frozen on both sides at the same time. When this process is used the food is packed in cartons, ready for distribution, before freezing. The other methods require that wrapping be done after freezing.

The handling of frozen foods during storage and shipment is of utmost importance and creates one of the most difficult problems the industry has to meet. Although the solidly frozen products thaw very slowly, fluctuations in temperature are not desirable. Small shipments, going directly to the consumer, will travel satisfactorily in well-insulated cartons, but for transportation to warehouses and markets it has proved best to ship in quantities large enough to fill a refrigerator car. In cold-storage warehouses and in markets special attention must be paid to refrigeration temperatures. When properly stored, quick-frozen products are thought to be practically imperishable. The industry is so new that we do not actually know just how long such foods will remain in good condition, but already the superiority of quick freezing over ordinary cold storage of fresh foods as been demonstrated.

Quick freezing is of importance commercially because it offers an effective method of preserving a surplus of fresh foods, thus equalizing supply and demand. It was first adopted by the fisheries whose great problem has always been prevention of waste of their extremely perishable product and its distribution to inland communities. Meat packers are using quick freezing to a considerable extent at present and find it to their advantage also. The freezing of fruits and vegetables is not as yet widespread. Certain kinds have proved well adapted to quick freezing, but the industry is still in its infancy and more experimental work is needed.

Quick freezing brings to the housewife food all ready for use — fish boned and divided into fillets, cuts of meat free from all waste, vegetables peeled and cut as they are ordinarily prepared for cooking, fruit and berries hulled or stoned, as the case may be. The package form in which all frozen foods are marketed enables her to buy by brand, a practice which, in the case of groceries, she has already endorsed.

CANNING

Canning as a method of food preservation is, in a sense, the exact opposite of refrigeration, for it utilizes heat instead of cold, to prevent the destructive action of micro-organisms. By heat, the bacteria which would cause food spoilage are actually killed, or, to use a scientific phrase, the food is "sterilized." The sealed can prevents the possibility of further contamination. Canned food is always cooked food, while food preserved by refrigeration remains in its natural fresh state.

It was during the Napoleonic War in France that canning had its beginning. At this time, the French government, in order to provide sufficient food for the navy during long voyages, offered a prize to the person who developed the best method of food preservation. The winner of the prize was a confectioner named François Appert. From his method, which consisted of sealing food in glass jars and cooking in boiling water, the modern canning industry developed.

At first canning was an uncertain process. For the most part, the canned foods kept satisfactorily, indicating that the principle involved was sound; but when they spoiled, as sometimes happened, nobody knew why. The making of cans and the preparation of food for canning required so much time and labor that often crops spoiled because they could not be taken care of quickly enough.

But gradually, spurred on by the increasing demand for canned food, and aided by increasing knowledge of the action of bacteria, canners solved all these problems. Machines which turned out cans at a rapid rate were invented. Machinery which replaced the hand labor of food preparation was designed. It was discovered that different amounts of heat were required for sterilizing different classes of food, and the autoclave, or pressure cooker, which produced temperatures far above the boiling point, was developed.

In a modern canning factory every detail of the process is carefully worked out. In the first place, the factory is located where crops are most abundant, so that the freshest of produce in perfect condition can be secured. The food is sorted and graded for size. Then it is peeled, shelled, or trimmed as its nature requires, packed in the kind of can best adapted to keeping it in good shape, and weighed to give full value.

Before the cans are sealed, the food is heated by being carried for just the right number of minutes through a steam chamber or hot water tank. This is to drive out the air. Then the cans are sealed and the cooking, or "processing," takes place. The temperature and time for complete sterilization of each product and for each size of can has been carefully worked out. Some foods are processed at the boiling point; for others higher temperatures are necessary. The time varies from twenty minutes to two or three hours. Each step is carried on by means of cleverly devised machinery which almost seems to have human intelligence.

Food which has been properly canned will remain in perfect condition for years. Though a cool uniform temperature is best for storing canned goods, they will withstand a wide range of temperature, and so can be successfully distributed in all parts of the world. The ever-growing list of products put out by canneries proves that there is hardly a food or food combination which cannot be preserved by this method.

Courtesy of National Academy of Sciences

THE MARCH OF SCIENCE

By Mary Ellen Whelpley

GALTON

(1822–1911)

SIR FRANCIS GALTON was a cousin of Charles Darwin. Like his cousin, he traveled a great deal. During his travels in South Africa, he discovered a tribe of natives which had become completely separated from the rest of their people and so developed different customs and habits. The characteristics of people had always interested Galton, and he now decided to devote his particular attention to anthropology, which is the science and history of the human race. The books he wrote on that subject were an important contribution to science. (Our studies of the human race are in Volume I.)

GIBBS

(1839–1903)

JOSIAH GIBBS is the second of the two Americans (Franklin is the first) included among the scientists for the bas-relief portraits which decorate the building of the National Academy of Sciences and the National Research Council in Washington, D. C. He was a great physicist. His studies and investigations have helped to solve some of the most difficult problems offered by complicated machinery. (You will find out more about his work on page 40 of this volume.)

HELMHOLTZ

(1821–1894)

IT occurs sometimes that two scientists working in different places may arrive at the same general conclusions. While Joule is usually considered as the discoverer of the law of conservation of energy, Hermann von Helmholtz is placed with him because he gave a firm and mathematical basis for this law. (You will want to read what he says about the energy which is to be found in the "storehouse of nature," on page 39 of this volume.)

DARWIN

(1809–1882)

CHARLES DARWIN was one of the most famous naturalists of the late nineteenth century. You will be interested in the story on p. 383 of how he happened to go on the five-year voyage with which he began his studies. His book, "The Origin of Species," with its theory of evolution, produced a sensation in the scientific world and created much discussion in both scientific and religious circles. To-day scientists regard him as one of the keenest observers and most original thinkers of modern times.

LYELL

(1797–1875)

WHAT makes our rivers, valleys, and mountains as they are now? A geologist of the present day knows how to read the true history of the earth. That is, he can explain just what has caused rivers to be in one place and mountains in another. However, there was no science of geology until Charles Lyell began his studies. (You may read more about him in Volume I, page 272.)

FARADAY

(1791–1867)

ELECTRICITY, as you know, moves trains, turns mill wheels, and does a thousand other things which require power. The machine which generates the electricity for these things is called the dynamo. Then the electricity generated in this manner can be carried along copper wires to the place where the power is needed. Michael Faraday discovered the most important law of the dynamo. (You may read about his discovery on pages 38 and 68 of this volume.)

BERNARD

(1813–1878)

CLAUDE BERNARD was born near the small village of Villefranche in southern France. He went to the college at Lyons, but left before he received his bachelor's degree in order to work in a druggist's shop. Here he acquired a practical knowledge of the way in which medicines were prepared.

Although he was to become one of the world's greatest doctors, at that time he hoped to have a literary career. He had written a vaudeville comedy, "La Rose du Rhone," which had been played with some success, and this encouraged him to write a tragedy in five acts. With this play, and a letter of introduction to a famous critic, he set out for Paris to seek his fortune as a writer.

The critic saw some merit in the play; however, he advised young Bernard to study medicine in order to gain a more secure means of earning a living. As a result of the critic's advice, the young man began his medical studies at the Sorbonne. Here he was such an outstanding student that Magendie, who was the most famous physiologist in Europe at the time, chose him for an assistant. So splendidly did Bernard carry on the experiments connected with the teaching, that Magendie exclaimed at the close of one of the lectures. "You are a better man than I."

By the time Bernard received his degree as Doctor of Medicine from the Sorbonne, it was evident to all his professors that he was a man of unusual brilliance, and a position in general physiology was created for him. In the next twenty years he made important discoveries for physiology.

Before Bernard, each organ of the body was supposed to have only one function. No one understood how closely all the organs were related with one another. Among other things, Bernard showed how bodily activities were regulated by the nervous system and how food was digested. His work was considered so important to the science of physiology that he was three times awarded the grand prize of the French Academy of Sciences. He died in 1878 and was given a public funeral at the expense of the state. Such an honor had never before been given to a man of science. In fact, Lavoisier, the great chemist, had been guillotined less than a hundred years before.

CARNOT

(1796–1832)

STEAM engines were once very crude affairs. Unless scientists had studied the relation between heat and the power to be gained from it, engines could not have developed into the powerful machines which they are to-day. Nicholas Sadi-Carnot's investigations provided one of the basic laws for the efficiency of the steam engine. (You may read more about his work on page 39 of this volume.)

Courtesy of National Academy of Sciences

JOULE

(1818–1889)

IN the early nineteenth century, scientists were also puzzled by the difficulty of telling just how much work, or energy, would produce a given quantity of heat. For instance, when a horse walks round and round, no one can measure exactly the amount of strength which he puts forth. To prove that energy by itself can produce heat, it is necessary to measure just how much work produces a definite increase in temperature. James Joule worked out the formulas which state this relation. (You may read his story on page 39 of this volume.)

MENDEL

(1822–1884)

GREGOR JOHANN MENDEL was born of an Austrian peasant family. He became a monk at Brünn in Moravia at the age of twenty-five. With the exception of two years when he was studying in Vienna, he spent all the rest of his life in the quiet monastery, first as a teacher and then as the abbot. However, in the gardens of the monastery, he experimented with breeding plants. He wanted to find some evidence of the laws of heredity. Year after year he watched the peas in his garden, keeping careful records of how different kinds and cross breeds inherited different forms and colors. From this observation of hundreds of generations of plants, he worked out his theory as to the inheritance of form and color in peas.

In 1866 he published several papers explaining his theory as to inheritance in the *Proceedings* of the Natural History Society of Brünn, but they were scarcely noticed. Not until 1900, sixteen years after Mendel's death, was the importance of his work recognized. Now, his law of heredity is regarded as one of the greatest discoveries in biology.

MAXWELL

(1831–1879)

WHEN you are listening to the radio, did you ever think how much preliminary study and research was necessary before you could hear a program "on the air"? James Clerk-Maxwell showed that electromagnetic action travels through space in waves like those of light. This was one of the early discoveries which led to radio communication. (You may read his story on page 40 of this volume.)

LOUIS PASTEUR — GREAT SCIENTIST AND BENEFACTOR OF MANKIND[1]

(1822–1895)

WHEN, recently, thousands of high-school boys and girls from all over the United States and from thirty other countries were

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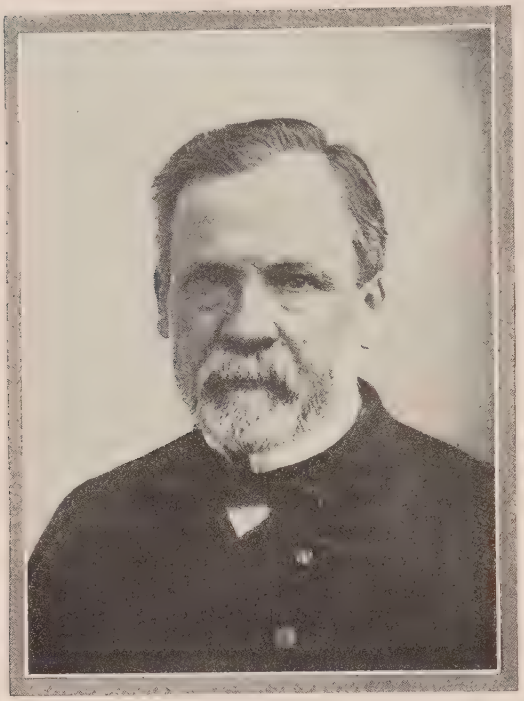
[1] By R. W. Hatch.



LOUIS PASTEUR

given an opportunity to express their judgment as to who should be considered the greatest world hero — excluding founders of religions and persons now living — they selected not a famous statesman, general, or explorer, but rather a man, who through years of intense study and painstaking experimentation, discovered the means for conquering some of the most deadly diseases which attack men and animals, and is said to have "saved more lives than Napoleon took in all his wars." This great-hearted genius, deeply loved by his own countrymen and honored the world over as one of the outstanding benefactors of mankind, was none other than the French scientist, Louis Pasteur.

Two days after Christmas, in 1822, Louis Pasteur was born in Dôle, France. In a few years his parents, (Jean) Joseph and Jeanne Pasteur, decided to move their little family to the neighborhood of the college town of Arbois. Although his parents had had little opportunity for schooling, they were people of high intelligence and nobility of character. From the first they took great interest in seeing that their son obtained the best education possible. Even when a boy, Pasteur was eager to learn, but, although he worked hard, he was considered only an average student. In fact, his father was rather disappointed to observe that his son, even at the age of thirteen, showed no apparent preference for anything but drawing.

In 1843 Louis Pasteur realized his ambition of entering the École Normale, where he immediately began to show marked ability and originality in working out experiments and in scientific writings. He much admired some of the great teachers whom he met here and they, in turn, were proud of him. His fellow-students called him a "laboratory pillar."

His whole family watched the young Pasteur's progress with the greatest eagerness and interest. It is said that his sisters counted the days before his letters would arrive. Knowing his father's great desire for knowledge, Louis now became his tutor by correspondence. Often he sent gifts to the family which he had purchased from his savings, even though he had none too much for his own food and comfort.

At Strasburg, Pasteur met Marie Laurent, the charming daughter of the new rector, and, only two weeks after this first meeting, the young professor had written to her father to ask for her hand in marriage. The request was granted, and the ceremony soon took place. Madame Pasteur proved an invaluable helpmeet to her illustrious husband, giving him sympathetic encouragement and cheerfully adapting her plans to the demands of his work. As the years went on, four daughters and a son came to make their life even happier.

In 1853 Pasteur was given the ribbon of the Legion of Honor and nine years later was made a member of the Académie des Sciences.

The year following June, 1865, was one of great sorrow for Pasteur, for, one after another, not only his father, but two of his daughters died. The eldest daughter had passed away six years before. He felt each of these losses very deeply, and it hardly seemed as if he could go on with his work.

Pasteur had already begun the great discoveries which were to mean so much to his country and to the world — discoveries in the realm of bacteria, those tiny organisms that work for good and for harm but are so small that they can be seen only under the microscope.

So little had been known about these tiny creatures before Pasteur's experiments that he really gave rise to the new science of bacteriology and laid the foundations of modern surgery which is performing such miracles of healing in our hospitals to-day.

The first problem that Pasteur attacked was presented by the serious difficulty which had arisen in the wine industry. The export trade was being ruined because French wines easily spoiled. After long experimentation with the bacteria which cause fermentation, Pasteur proved that if wine were heated to a certain temperature and kept there for a given length of time, it would remain in good condition almost indefinitely. This same principle is utilized in destroying the harmful bacteria in milk by the process which we call PASTEURization.[1]

Great consternation reigned in southern France, where a large percentage of the population depended upon the silk industry, because some deadly disease had attacked the silkworm. No one seemed to have any idea as to the cause or the cure of this disease. Pasteur was sent for. Although he had never before even touched a silkworm, he was able, after several years of concentrated study and experimenting, to determine the nature of the bacteria and point out how the disease might be controlled.

While in the midst of his research on the silkworm disease, the great scientist, only forty-six years old, was suddenly stricken with paralysis. So certain did his death seem that the men who had begun construction on a much-needed laboratory, stopped work. Pasteur's great accomplishments, however, were not finished. Gradually his health improved and even when he was still very weak he insisted on going on with his work, for he felt that one man's life was useless if it was not useful to others.

He was happy, in 1873, to be elected to a place in the Free Associates of the Academy of Medicine, because he wanted to work on the prevention of contagious diseases.

The French government, wishing to express some of the profound gratitude which the entire nation felt, voted to give Pasteur a life annuity of 12,000 francs. Many of his friends now urged the great scientist to take the rest which he so much needed and to spend the remainder of his life quietly with his family, but he felt that his service to the world was not yet completed.

Anthrax or splenic fever was now running rampart among sheep and cattle. After many experiments Pasteur discovered a vaccine which would make animals immune to this disease. As he had many grateful friends, Pasteur also had bitter enemies among those who would not accept his theories about bacteria. These antagonists often bitterly attacked him — his theories, his methods, and even his honesty; and they aroused distrust among the peasants, which often seriously hampered his work. Such opposition irritated Pasteur, and it is a matter of regret that he spent much time answering the charges which time would eventually have silenced. Doubts concerning the efficacy of the vaccination against anthrax were destroyed by a very dramatic demonstration. Fifty sheep were selected. Twenty-five were vaccinated and twenty-five were not. All were then inoculated with the disease. Within four days every one of the unvaccinated sheep had died and not one of the others had succumbed to the disease. The most pessimistic doubter could now hardly fail to accept the new discovery.

When parts of France were attacked by yellow fever, Pasteur began research on this disease. His friends warned him against infection, but he only replied, "Life in the midst of danger is *the* life, the real life, the life of sacrifice, of example, of fruitfulness." It was a source of deep grief to him when one of his young assistants, a man of brilliant promise, while working with him on a cure for cholera, contracted the disease and died.

When Louis Pasteur was a small boy living in Arbois, he had been greatly impressed by the stories of a mad wolf who had bitten many people, causing them to suffer terrible agony and finally die. The mystery of this dread disease, hydrophobia, had never ceased to haunt his mind, and it was one of the greatest satisfactions of his life that he should live to discover the cause and means of prevention. It was in 1880 that he was able to concentrate his efforts on this research. After five years of intensive experimentation on animals, Pasteur and his assistants felt very confident that they had discovered a vaccine that would prevent a person who had been bitten from developing the disease. The method worked without fail on dogs, but how Pasteur dreaded to try it on a human being! It had never ceased to be painful to him to see even a little animal suffer, and he could not bear to think of the consequences should his method fail on a human being.

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[1] See pages 298 and 299 of this volume.

On July 6, 1885, a little nine-year-old Alsatian boy, Joseph Meister, entered the laboratory, accompanied by his mother. Two days before he had been bitten by a mad dog and was now suffering greatly from his fourteen wounds. The decision as to whether or not to try his treatment on the boy was very painful to Pasteur, but it seemed to him that there lay the child's only chance of life. The treatments lasted ten days. A biographer of the great scientist tells how during the days of the last inoculations "Pasteur was going through a succession of hopes, fears, anguish, and an ardent yearning to snatch little Meister from death; he could no longer work. At nights, feverish visions came to him of this child whom he had seen playing in the garden, suffocating in the mad struggles of hydrophobia." On the last day of treatment "cured from his wounds, delighted with all he saw, gaily running about as if he had been on his own Alsatian farm, little Meister, whose blue eyes now showed neither fear nor shyness, merrily received the last inoculation; in the evening, after claiming a kiss from 'Dear Monsieur Pasteur,' as he called him, went to bed and slept peacefully. Years passed and the little boy remained strong and well and deeply grateful to the kind man who had saved his life."

Many people now began to come to Pasteur for treatment, some from as far away as New York. Again and again he was able to send them away in good health, but once in a great while someone would arrive who had been bitten weeks before, and Pasteur would be grieved to find that all treatment was in vain. Forgetting the vast majority of successes, his enemies used these very infrequent failures as the basis for attacks. Notwithstanding this opposition, more and more people came and a regular service was organized.

During the last years of his life it was a great joy to Pasteur to assist in training the young men who were to go on with his work. Although he was now very frail and weak, he still hoped to conquer one more dread disease — diphtheria. This his pupils were later able to accomplish.

In Paris, the great Pasteur Institute was being erected as a dispensary for the treatment of hydrophobia, a center of research on virulent and contagious diseases, and also a teaching center. On November 14, 1888, it was inaugurated — one of the great humanitarian institutions of modern times, a lasting memorial to the spirit that inspired it.

IN THE PASTEUR INSTITUTE

Dr. Metchnikoff, Second Director of the Pasteur Institute, and winner of the Nobel prize for medicine in 1908, in his laboratory.

On his seventieth birthday, Pasteur was made very happy by the expressions of honor and gratitude coming from many parts of the world.

For several years, in spite of the most devoted care from his family and his many disciples, his strength had been rapidly failing, and on an autumn afternoon in 1895, still preserving his absolute faith in a future life, he quietly passed away; but his ardent and benevolent spirit continues to be the inspiration of many a scientist who is consecrating himself to the task of freeing mankind from the clutches of pain and disease.

EXPLORING FOR SCIENCE—CHARLES DARWIN

"IF you can find one man of common sense who advises you to go, I will give my consent."

With these words Dr. Darwin answered his son's eager request for permission to go on a cruise around the world, and the tone in which he said *one man of common sense* indicated that he really meant *no*. Yet it seemed impossible for Charles to give up the splendid opportunity about which Professor Henslow had written The words of the letter danced before his eyes: — Fitz-Roy, captain of His Majesty's Steamship, *Beagle*, was willing to share his cabin with any young volunteer who would make the two or three years' cruise as naturalist.

In imagination young Darwin had already been discovering curious new plants in the luxuriant tropical growth on the Amazon, exploring the forest-clad mountains of Tierra del Fuego, and investigating the desert country of Patagonia. There was nothing he would rather do than study plants and animals in far-off countries. Now, unless he could find a man of common sense to recommend it, that trip must be given up. His father's disapproval brought him back to reality.

Reality was that Charles Darwin had just spent three years in the University at Cambridge preparing to become a clergyman. He had passed his B. A. examinations and was therefore ready to take Holy Orders. In his father's estimation two or three years' travel in out-of-the-way places was quite unnecessary for a preacher. Perhaps if young Charles went off on a wild goose chase like this one, he might never be ready to settle down in England. His record at school had not been very promising. One of his teachers had charged him with being a *poco curante*, or careless person, for wasting time on useless subjects. Then, too, the boy had already changed his profession once. The father had hoped that his son would become a doctor; but in Edinburgh where Charles had gone to study medicine, he had found the professors and lectures so dull that he had decided he could not go into that profession. During his three years at Cambridge, he had spent a great deal of money and had done only average work in his studies. So Dr. Darwin disapproved of the whole proposition. A restless fellow like his son had much better settle down in a quiet parish at home as soon as possible.

But why, if Charles Darwin was an idler, should the professor of botany at Cambridge have recommended him for the position of naturalist on a cruise of two or three years? That question Charles, himself, might have answered had his father asked it. Since his father did not make such inquiry, the boy wrote Professor Henslow that he must refuse the offer.

The career of Charles Darwin, scientist, might have ended right there. However, the "man of common sense," who saw more than the school records showed, appeared at just the right time. That man was Charles' Uncle Josiah, his mother's brother.

The morning after the letter to Henslow was written, Charles went to his uncle's home in Maer for the fall hunting. He loved shooting and riding, but he also enjoyed the perfect freedom of life at Maer. In the summer (and this was late August) the whole family used to sit talking on the steps of the old portico. There was a flower garden in front and a lake which reflected a steep wooded bank. Perhaps it was here, where you might see a fish rise from the water or a water bird paddling about, that Charles and his uncle sat discussing the project which was to change the whole course of the young man's life. For Charles had taken the letter from Professor Henslow with him, and "Uncle Jos" did not agree with Dr. Darwin at all. On the contrary he thought the expedition a very wise one. And if ever there was a man of "common sense," that man was Josiah Wedgwood. While he was rather silent and reserved, he had often talked freely with his nephew. Charles knew that if "Uncle Jos" believed a certain thing was right, he would do everything in his power to promote it.

In this case he did not hesitate a moment in writing to Dr. Darwin and answering all his objections to the proposed trip. It must have been that "Uncle Jos" saw that in reality there were two Charles Darwins. The first one had been content to go through school with the least possible study. That was because the second one was deeply interested in something that lay outside of the required subjects. Of course, it was that second Charles Darwin whom the professor of botany was recommending as a naturalist.

It is the second Charles Darwin, the one who did not show in the school records, in whom we are interested, too. What kind of a boy was he, and what did he have to show for his twenty-two years?

As a matter of fact, his tendencies are shown very early. Most small boys ask a great many questions. They want to know the "whys" and "wherefores" of things. Charles' curiosity set him not only to asking questions but also to examining everything that he saw. Before he was ten years old, he was an eager collector of shells, birds' eggs, insects, minerals, and all sorts of other things. He examined the pebbles in front of the hall door and wanted to know something about each one. When he saw a curiously shaped bowlder called a "bell-stone," he wanted to know how it came to be in their town of Shrewsbury. Similar rocks were to be found only in Cumberland or Scotland. Since no one then understood that glaciers had once overrun the country, he was told that the world would come to an end before anybody could explain how it got there. That answer set him to wondering even more about the wonderful stone.

On a trip to Wales when he was only a little past ten, he discovered that the insects and moths were different from those at his own home. A great many older people would not have noticed such a difference. However, although the boy did not care for his school books, he had read White's *Natural History of Selborne*.[1] Before long he was making note of the habits of birds and animals which he observed. He had so much fun doing this that he wondered why every gentleman did not become an ornithologist.

A few years later Charles and his brother Erasmus secretly rigged up a laboratory in the garden tool-house. Sometimes they worked there until late at night. When his schoolmates found out that the two boys were working at chemistry, they nicknamed Charles "Gas." This interest in practical experiments led him to read several books on chemistry. However, Dr. Butler, head of the school, could only see that he was wasting time on useless subjects. Even his father reproached him, saying, "You will be a disgrace to yourself and all your family."

A change of schools seemed to be the solution, and Charles was sent up to Edinburgh to study medicine. No doubt he had every intention of doing well there and pleasing his father, for he speaks of the doctor as being "the kindest man I ever knew." Soon, however, he found friends who were interested in natural history. Medical studies suffered accordingly. It was far more exciting to go out with young Dr. Grant to collect marine animals than to listen to a dull lecture on anatomy. Sometimes the fishermen with whom he became friendly let him go with them when they trawled for oysters. In this way he got more specimens. Then he learned to stuff birds and became acquainted with the curator of the museum who gave him rare shells. He also attended meetings of the Natural History Society and once heard the great Audubon talk about North American birds. All this was not going to make a doctor of him, though, and at the end of the second year Dr. Darwin again decided that his son was wasting time. Another change of schools, and Charles went up to Cambridge to become a divinity student.

Charles Darwin has said that his three years at Cambridge were "sadly wasted" and "worse than wasted." Yet they were important years; for his love of science in open-air forms increased, and he came to know Professor Henslow. Henslow, whom Charles regarded as "the most perfect man" he had ever met, was a teacher who did more for his students outside of the lecture room than in it. He kept open house once a week, and Darwin went regularly. Before long he was joining the older man on long walks and excursions around Cambridge. To a good many people young Darwin became known as "the man who walks with Henslow." Sometimes they went by foot into the fens and waste places, sometimes by coach on long expeditions, and sometimes by barge down the river; but always they were searching for rare and interesting plants.

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[1] Notice how Dallas Lore Sharp recommends and gives quotations from this famous book. Volume Three, pages 40, 266–267 and 300.

Charles had never outgrown his passion for collecting. During these Cambridge years he managed to gather together a remarkably fine collection of beetles. At one time when he was tearing off the bark of a tree, he saw two rare specimens. He seized one in each hand and then he saw a third, a new kind that he felt he must have. He popped the one which he held into his mouth. However, it ejected an intensely acrid fluid which burned his tongue so that he was forced to spit it out. Thus he lost not only that beetle but also the third one. Usually, however, he got his beetle.

So eager was he to find new beetles that during the winter he hired a laborer to scrape moss off old trees and place it in a large bag, and also to collect the rubbish in the bottom of the barges in which reeds were brought up from the fens. In this moss and rubbish he found some very rare species. He had the fun of seeing in Stephen's *Illustrations of British Insects* the mention of a rare beetle with the "magic words 'Captured by C. Darwin, Esq.' " The young man was as thrilled about this as a poet would be at seeing his first poem published.

After Charles passed his B. A. examinations, he still had to spend two terms in Cambridge. At Professor Henslow's suggestion he took up the study of geology again. He had attended some lectures on that subject at Edinburgh, but they had seemed incredibly dull. Now, however, he found the study so fascinating that he worked "like a tiger" to make a geological map of Shropshire. Then he went on a geologizing trip into Wales with Sedgwick, the professor of geology. He had just returned when he found the letter from Henslow.

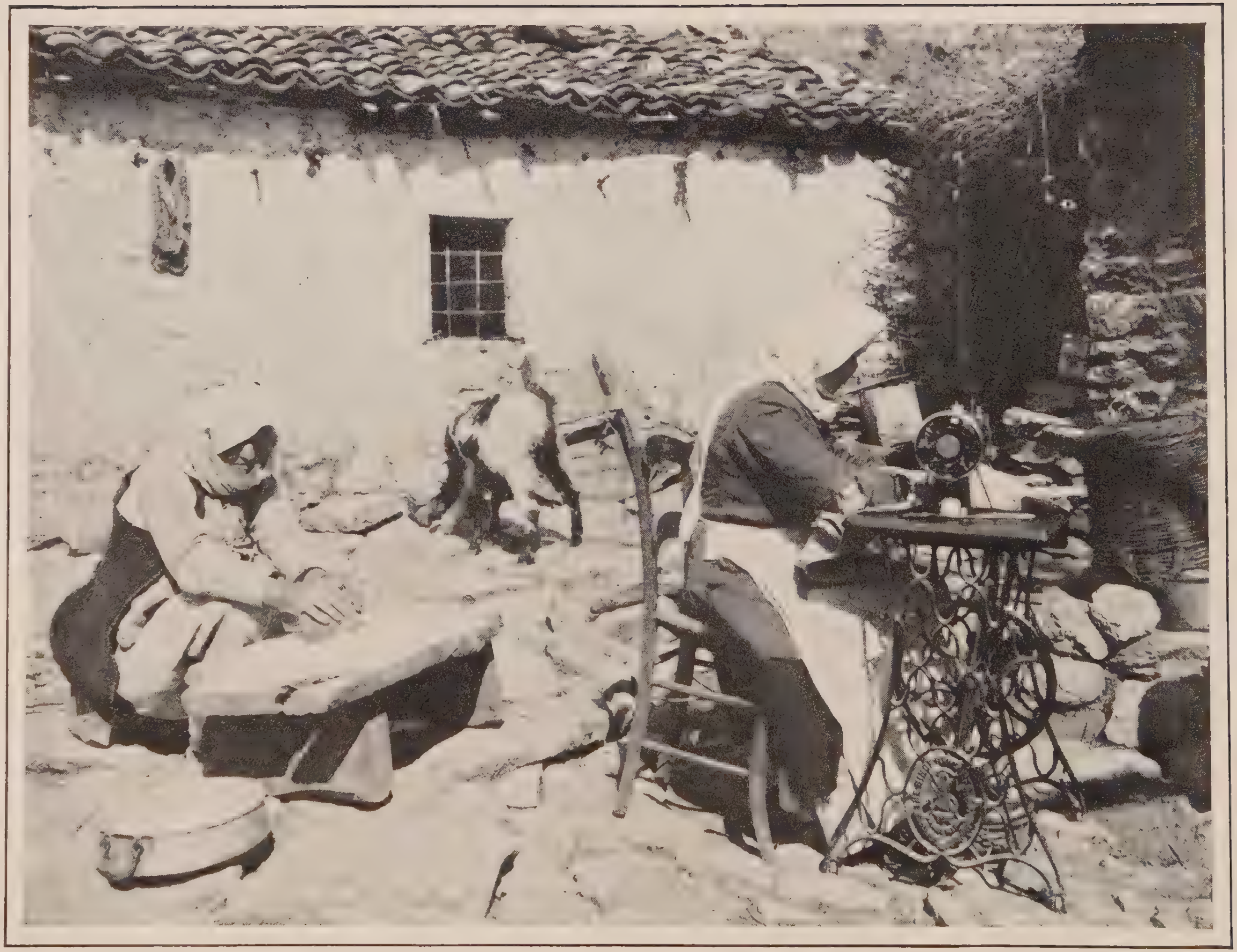
What a tragedy if all this eagerness and interest in the world of living things had gone for naught! Thanks to Josiah Wedgwood they did not. After writing to Dr. Darwin, "Uncle Jos" seems to have feared that a letter might not be sufficiently persuasive. So he and Charles followed up the letter, driving the thirty miles to Shrewsbury in order to talk it all over. The doctor had to concede that "Uncle Jos" was not only "a man of common sense" but one of the most sensible men in the world. He seems to have been won over fairly easily, for Charles says that his father "at once consented in the kindest manner."

As Darwin wrote to a friend a few days later, "There is indeed a tide in the affairs of men. . . ." Immediately he hurried off to see Henslow and then to Fitz-Roy, the *Beagle's* commander. Here a trivial circumstance almost stood between him and the voyage. Fitz-Roy, who thought he could judge a man's character by his features, did not like the shape of the young man's nose. However, he did decide to risk the nose and accepted Charles Darwin as his naturalist and cabinmate on the long cruise.

Two months of preparation dragged on before the vessel was ready to sail. This was a "miserable" time to the eager young man. Of the actual sailing, he has said, "My second life will then commence, and it shall be as a birthday for the rest of my life."

These words were almost literally true, for that voyage, which lasted five years instead of the two or three planned, gave Darwin, the scientist, an opportunity to develop. Observations on coral reefs, lofty tropical ferns, the changing colors of the octopus or cuttlefish, red spiders, fossil remains of gigantic mammals, naked savages, and much more went into his notebooks. It took ten years to prepare all the material for printing; while in another ten years, these facts of plant and animal life which Darwin had gathered in every part of the world provided the basis of an entirely new theory of life. But for his voyage on the *Beagle*, "The Origin of Species" might never have been written. And this voyage depended on the splendid common sense of one man — "Uncle Jos."

The voyage of the *Beagle* lasted five years, from December 27, 1831, to October 2, 1836. This voyage became, by the presence of young Darwin, historic as a scientific expedition, predecessor of many which were to add to the knowledge of the wonders of the natural world in our own day. More than three years were spent off the coast of Patagonia and the west coast of South America. In September, 1835, they headed across the Pacific for Tahiti, New Zealand, Australia, and Tasmania. Then they went on through the Indian Ocean, round Africa and into the Atlantic Ocean. At St. Helena they again turned across the Atlantic to Brazil in order to complete the voyage round the world and finish the chronometrical measurements.



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ANCIENT INDUSTRY MEETS MODERN INVENTION

Although the natives of this small Greek town use the crudest of implements for home and farm, they quickly adapt themselves to the modern speed of the sewing machine.

Ewing Galloway

STEEL MILLS AT NIGHT

INVENTION AND INDUSTRY

> "Into the dust of the making of man
> Spirit was breathed when his life began,
> Lifting him up from his low estate,
> With masterful passion, the wish to create."
> *Van Dyke.*

WITH these words our book began; with these words it might well end. The creative instinct implanted in man has been responsible for all the inventions and industries which have contributed to make up our modern world, as they have been sketched on these pages; it will be responsible for the developments along these lines in the future. Man's progress in the past, wonderful as it has been, is probably but a forecast of his progress in the years to come. It is only within the last twenty-five or fifty years that the great system of modern industry has been built up. Within the memory of many of our readers, flying and talking through the air have been introduced as new elements of civilization. The creative instinct is never satisfied; it works in every generation to accomplish new wonders.

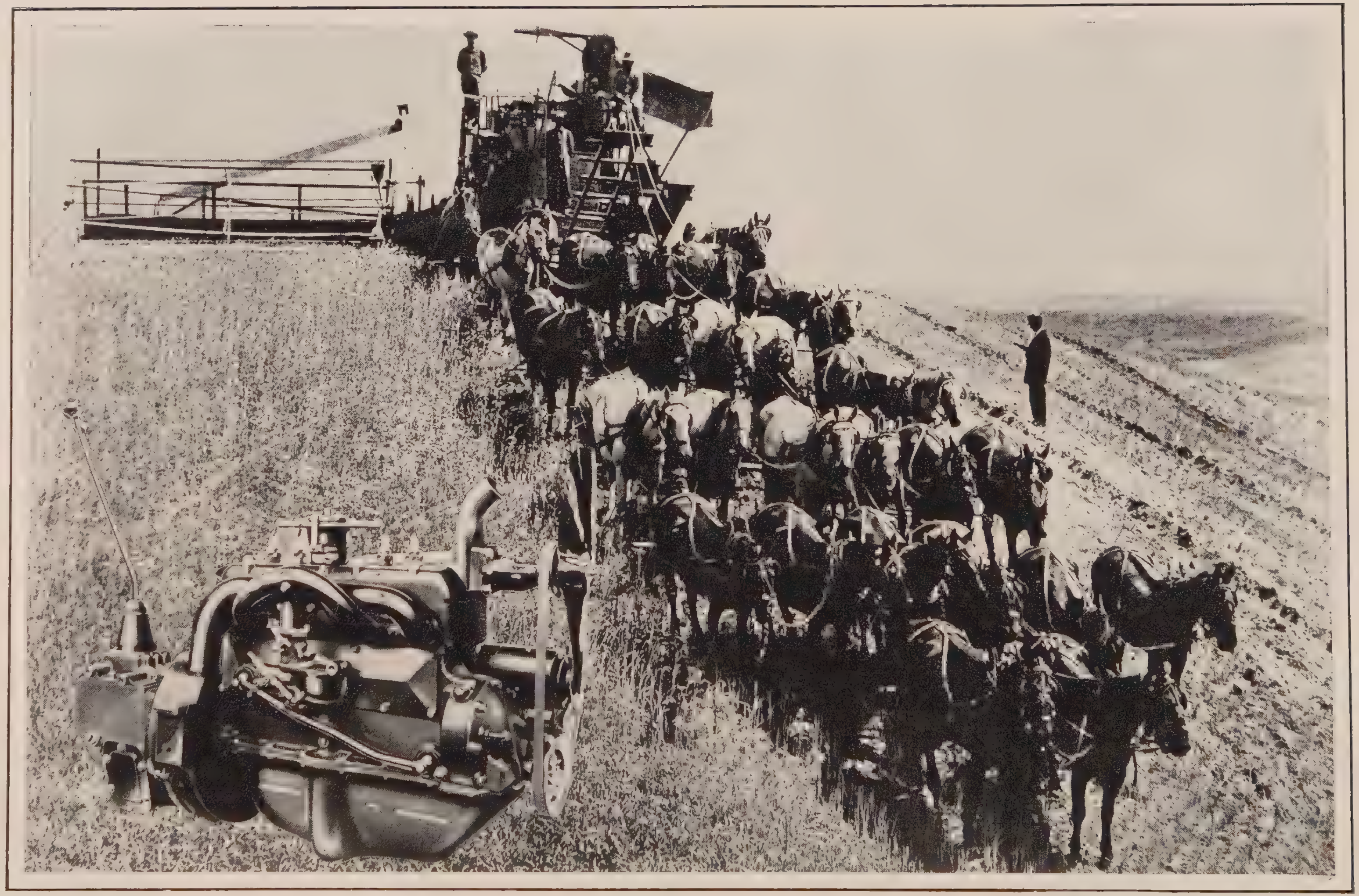
WHAT IS IT ALL ABOUT?

We have told the tale of inventions; we have followed the course of certain leading industries. We have touched again and again on the change that this new machine, this discovery, or this process has made in our daily life. Now let us pause to consider for a moment what is the goal towards which we are traveling. The creative spirit in man is working, but towards what ends? Are the scientists in their laboratories and the armies of workers in the factories all guided, however indirectly, by one ruling principle and towards one main objective? When we think back over the varied stories of this volume, we shall find that there is such a ruling principle which runs through every chapter, and that principle is that man has set out to conquer the world. In all his undertakings he is fulfilling the ancient command of the Garden of Eden to subdue the earth and to have dominion over it. As we think over the inventions and accomplishments of the past fifty or one hundred years, we shall see how rapid has been his recent progress, and how great is the promise of the next century or half-century.

If we were to sum up the three things that man desires most, beyond the bare necessities of daily life, they would seem to fall into three main groups, — to become more independent of space, to become more independent of time, and to relieve himself of heavy bodily labor. The more gain he makes in any one of these directions, the freer is his life in this world in which he finds himself. Let us, therefore, trace out our inventions and industries with these ideas in mind.

HOW MAN IS SAVING HIMSELF HEAVY LABOR

Labor saving began with the introduction of machinery. The moment that inanimate objects fashioned from wood or iron can be made



Photos, Ewing Galloway; Ford Motor Co.

TWO KINDS OF HORSE POWER

An old time thirty horse team and a thirty horse-power automobile engine

Photo, Ewing Galloway

BLASTING AWAY A MOUNTAIN

This snapshot was taken a small fraction of a second after the charge of dynamite planted deep in the side of the mountain had been touched off.

by the introduction of some source of energy to do work for man, that moment he is relieved from the necessity of making his own bodily machine supply all the energy and all the mechanical adjustments for doing the work he wants done. Man's first method, and one which he still uses to a large extent, was to provide machinery for which animals could supply the driving force. His unit of measure was for such a long period the power that one horse could supply that even to-day the working capacity of an engine is often reckoned in its "horse power." Yet how limited is the range of a machine depending on horse power compared with that of one driven by some fuel-using machine! In our photograph taken on the wheat fields we have a striking example of horse power, raised in this instance to the thirty-third degree, but, splendid as that team of horses is, how bulky and difficult of direction it is compared to the compact automobile engine shown beside it. In that neat motor, capable of transforming gasoline and electricity into the power of many horses, we get a symbol of potential energy as it is doing man's work in the modern world of machinery.

A FUEL-USING AGE

For the running of his engines man is depending chiefly on the fuel which he finds stored in the earth. We have followed the story of the steam engine, with its contribution towards doing the work of the world. The steam engine is adapted to the use of a fuel like coal; it would seem as though it would be used so long as the supply of such fuel continues. But the steam engine could never have been utilized for such machines as an automobile or an airplane. One can hardly picture an aviator carrying along the contents of a coal bin or an automobilist as having at the rear of his machine a fireman or stoker to replenish his fire. Here oil enters as an available fuel and makes possible the internal-combustion engine, described so fully and clearly in an earlier chapter.

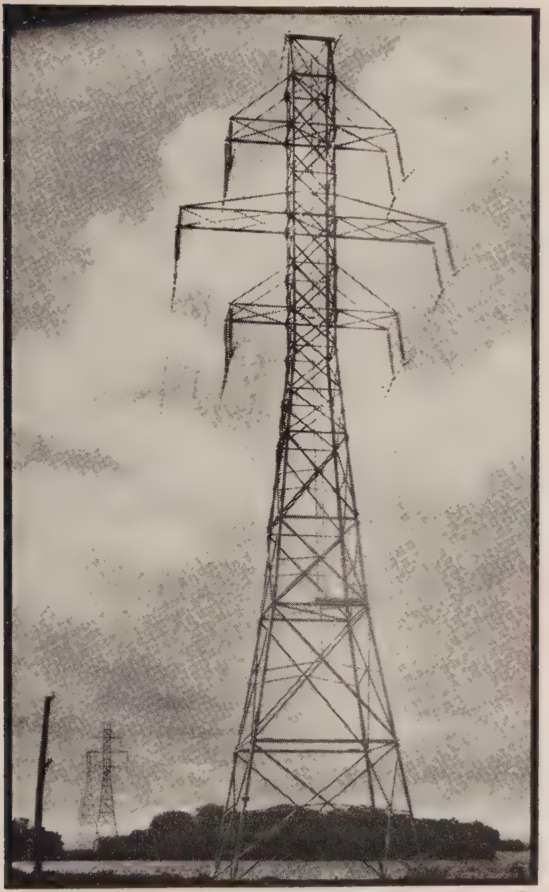
Man's work, then, is being done in large measure by the heat of combustion, or, in simpler language, by burning. And what is combustion or what is fire? From the chemist's point of view it is the heat-producing union of two elements such as carbon and oxygen or hydrogen and oxygen. The oxygen is in the air, and therefore easily accessible and manageable. Carbon is stored away in the earth in the form of coal; but it is a solid. It must be dug up from the earth, transported, and

Photo, Ewing Galloway

ELECTRIC WELDING OF STEEL

By the concentration of intense heat at a single spot, this workman can accomplish easily what no man-power unaided could achieve.

shoveled into the firepot. Petroleum is likewise stored in the earth; it is a fluid. It is imprisoned under such heavy pressure that it is ready to gush forth when an opening affords the least chance; it is easy to transport; and it will flow into an engine under some system of automatic control. Crude petroleum would not be suitable for the internal-combustion engine, but gasoline, distilled from petroleum, does provide the ideal fuel-fluid, having a combination of hydrogen and carbon, which puts it in the class of "hydrocarbons," giving good heating results, being clean and easy to handle, and being easily converted from its liquid state into a gas for combustion. The use of fuel for power in steam and internal-combustion engines has been at the basis of our modern machine-driven civilization.



Courtesy Beauharnois Light, Heat and Power Co.

HIGH VOLTAGE ELECTRIC TRANSMISSION LINES

ELECTRICITY AND CIVILIZATION

From the mechanical point of view the great call of the world is for energy which shall keep things going. If you turn to Volume X, you will read in the opening chapters how all life depends on and utilizes the energy from the sun. Our whole world is run by energy supplied from that distant but all-important central body about which the earth takes its course. If we are in danger of becoming boastful over man's machines, the story of energy as utilized by Nature in her living machines will make us duly humble concerning man's small successes in acquiring and applying the sun's energy as it pours in on the earth. "The work of the world," it has been concisely said, "is done by sun power. Whether it be accomplished by the muscular labor of horses or human beings, by the whirling of windmills or water wheels, by the burning of wood, coal, or oil, or by the swift and silent electric current, the energy comes directly or indirectly from the solar reservoir."

This energy we can neither make nor create. We can only use what we find in the world about us. One big source is in our fuel supplies, which furnish chemical energy by combustion; the other is in the waterfall, which furnishes hydraulic or mechanical energy. Fuel we can transport; water power we could not transport. "It was the electrical engineer who made the water powers of use," wrote Steinmetz, "by changing, 'transforming' the hydraulic energy of the waterfall into electric energy, to send it over the electric transmission line to the distant places where energy is needed, and distribute it as electric energy. . . . It is the characteristic of electric energy that it can be distributed and converted into any other form of energy in a very simple and highly efficient manner, and that the economy of distribution and conversion is practically the same, whether we want the minute amount of energy to ring our doorbell, or the power of hundred-thousands of horses to drive the propellers of the battle cruiser. . . . Electric energy thus is the form of energy best suited for the transmission and supply of the world's demand for energy."

Electric energy is unique in this particular.

It is all produced by conversion from some other form of energy. There is always a generator, producing mechanical energy, as from water power, or a battery, producing chemical energy. But as we have seen in our story of "Electricity" in an earlier chapter, and as we shall see in the story of the use of water power in Volume IV, it is useful beyond measure as an intermediary for the transmission and ready delivery of energy for our instant and efficient use.

Electricity is man's newest servant in the march of civilization. In saving him labor by doing his work for him, and by extending his powers, its present use is enormous, and its service in the near future is incalculable.

APPLIED SCIENCE AT NIAGARA FALLS

One of the most interesting places in the world to study the results of applied science is the great manufacturing district that now centers about Niagara Falls, where the tremendous electric energy produced by almost unlimited water power has been harnessed for the benefit of mankind.

Most of the industrial processes carried on at Niagara make use of the electric furnace. This generates heat within itself without combustion and produces temperatures that far exceed those obtainable from furnaces using fuel. The limit of the temperature of the electric furnace is about 6692° F., the temperature at which the carbon lining of the furnace boils away. This is three times as high as the melting point of cast iron. The electric furnace is also highly efficient, as from fifty to seventy-five per cent of all the heat developed can be applied, a far larger proportion than is the case with fuel-fired furnaces.

Aluminum is the most useful of the light metals. It is found more abundantly in Nature than iron; yet until a way was found to manufacture it electrically the metal cost nearly a dollar a pound. In 1889 an American chemist, Mr. Charles M. Hall, discovered that aluminum oxide could be easily dissolved in certain salts — double fluoride of aluminum and the alkali metals — and that the passage of an electric current through this solution, when heated and fused, produced pure aluminum. By this method it can be manufactured in great quantities and at low cost.

CARBORUNDUM

Another product of the electric furnace is carborundum, a most efficient polishing material and one of the hardest abrasives in the world. It is extensively employed as a substitute for emery in whetstones and grinding wheels. This, too, was discovered by an American, Mr. Charles E. Acheson. It is made by heating a mixture of sand and carbon to the temperature of the electric arc, and is a dark, crystalline substance, the surface of which is noticeably iridescent. Mr. Acheson is also the inventor of artificial graphite, which is a product of the electric furnace. No other temperature is sufficiently high to convert ordinary carbon into the soft, slippery graphite, which is even superior to the natural product found in Ceylon and Siberia. Graphite is used largely for lubricating machinery.

In addition to the products described, the electrochemist has been responsible for the development at Niagara of the production of calcium carbide, metallic sodium, chlorine and caustic soda, electrolytic chlorates and alundum, and the ferro-alloys. These last are alloys of iron with the more expensive metals, used in manufacturing steels of various kinds. Some of these metals are nickel, tungsten, molybdenum, manganese, chromium and vanadium. They are used in alloy steels such as stainless steel, spring steel, armor plate and tool steel.

MAN'S GROWING CONTROL OVER SPACE AND TIME

In an essay on the automobile Maeterlinck says, "Space and Time, its invisible brother, are perhaps the two great enemies of mankind. Could we conquer these, we should be as the gods." Our machinery has done much towards giving man this conquest. Run through the inventions as they have been listed and see how they conquer space, and therefore time: the steam engine, and with it the development of railroads and of steamboats for ocean travel; the internal-combustion engine, and with it the automobile, the farming machinery which enables man to extend his cultivation of the land, the motor boat, and the airship; the electric battery or generator, and with it the telegraph, the telephone, and the radio system, — all these have brought man within the last fifty years into a most remarkable independence of the limitations of space. Even the Arctic explorer reports his adventures back to the civilized world by radio, and a President of the Unites States may sit in the White House and talk to an audience comprising the whole United States, with the possibility of a fringe of hearers "listening in" from other lands.

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EDISON AND STEINMETZ

Two of America's foremost inventors comparing notes in a laboratory.

Commerce is the handmaid of intercommunication. Man is a born trader. If he talks with anybody, he will exchange products with them. So our industries reflect to an amazing degree this independence of space. A writer has well illustrated the manner in which we touch the ends of the earth in even so simple, as it would seem, a process as the manufacture of a pair of shoes: "The welt is cemented to the sole with a mixture of asphalt, probably from Venezuela, and rubber, from Brazil or the Straits. The upper is sewed to the welt with linen thread made from flax grown in Russia or the Argentine and spun in Ireland or Scotland. The fancy stitching in the upper is of silk from China or Japan. The soft tops of high shoes are made usually of goatskins produced probably in India or China or South America. The tongue in high-grade shoes is likely to be Australian kangaroo skin. The metal eyelets for the laces are made of a composition of nickel from Canada, tin from Malaya or Bolivia, and zinc from Missouri or Mexico." We have told tales of foodstuffs from afar, and in this connection we should not fail to recall the "Scientific Refrigeration" which has made possible the shipping of meats and fruits and vegetables. The pioneer farmer would consider the array of foods which we spread on our tables at all seasons of the year nothing short of miraculous. Kings did not fare so sumptuously in former days. It would seem as if perishable foods could be transported anywhere and kept in some form almost indefinitely. We sympathize with the man who threatened to write the romance of the tin can, that sealed container from which come forth at our touch such a variety of products.

Photography and printing have done much to obliterate time and space. The scene of a moment is caught by the camera and flashed to us so quickly that we can see within a few days or hours of the event kings crowned or volcanoes in eruption. The people and customs of other lands are made so familiar to us that we lose the sense of strangeness which is the barrier formed by distance. The printed word serves as does the telephone and the radio to do away with the limitations of both distance and the passage of time.

MATERIALS AND THEIR POSSIBILITIES

As we trace back the machines which work miracles in our daily life, we find that they were designed in the workshop of the inventor. As we study the industries, we learn that the scientific formulas for the combination of this substance with that were evolved in the laboratory of the scientist. It is well, therefore, to take a look into these places of quiet investigation and experiment. We shall find out how some of the achievements of the past have been accomplished and why new wonders are to be expected in the not far distant future.

Man's conquest of the world depends on his understanding of the materials out of which the world is made. If he can know how to handle inanimate things like wood and iron and the juice of the sugar cane and the milk from the rubber tree, he can gain a mastery over them which will make them serve his purposes. When we take the long look at things, we see man as a stranger put down in a world of wonderful, unknown materials, each of which he may test and test again to gain its secrets and know its possibilities. It is in the study of materials that man has made some of his most conspicuous recent progress.

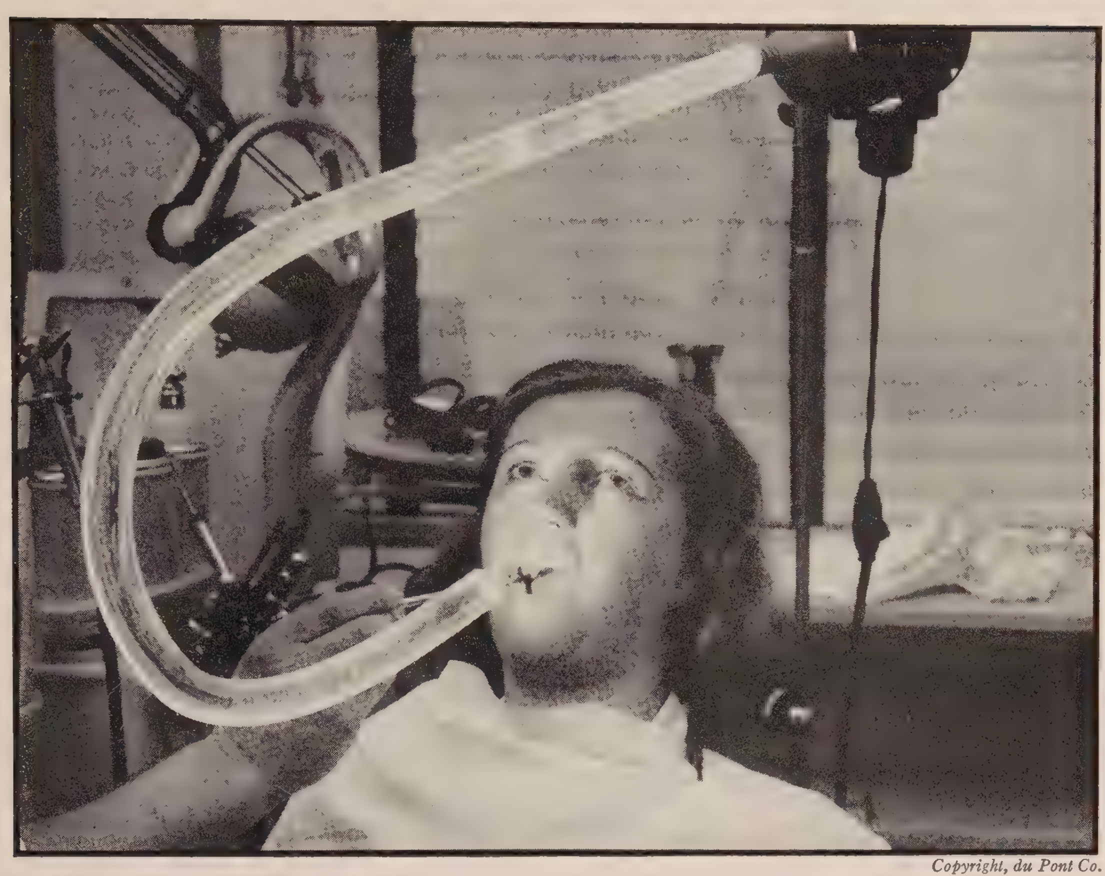
THE CHEMIST AND HIS WORK

To the chemist the world is a world of ninety or a hundred elements appearing in various combinations and with various properties due to these combinations. He does not ignore the life principle which enters in, but his business is to deal with these elements as they appear. Because he thinks and talks of elements in atoms and molecules, too small for any one to see, and labels these tiny invisible portions with letters of the alphabet as short-cuts so that he need not keep repeating their names, the chemist's books and even his talk are likely to seem over-learned and technical for the ordinary person to follow. But lately he has taken a great deal of pains to explain his problems and his interests in terms simple enough for the rest of us to follow with appreciation.

The charm of the chemist's job lies in the fact that while one half of his concern is to take things apart to see of what they consist, the other half is to put things together in new and different combinations. He would express this to you in two words, — "analysis," the taking apart, and "synthesis," the putting together.

Synthetic rubber, described on page 218 of this volume, also rayon and cellophane, described on page 263, are triumphs of chemical synthesis.

Another triumph of the chemist is in the field of synthetic plastics which are now used in the manufacture of a wide variety of articles, many of which were formerly made from natural products. The synthetic plastics are also called synthetic resins. This does not mean that they are made from the natural resins of trees, for they are not. It simply means that, although built up chemically from a variety of substances, they resemble the true resins in being lustrous, brittle at ordinary temperatures and plastic when exposed to heat and pressure. Many people think it odd that these substances are



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"PIPED LIGHT" COMING THROUGH A CURVED ROD OF "LUCITE"

called plastics, for as we find them in finished articles they are very hard. They are soft and "workable" at high temperatures, however, and can be molded into beautiful and durable toiletware, costume jewelry, ash trays, tableware, electrical appliances, lighting equipment, buttons and buckles, scuffless shoe heels, motion picture film, automobile accessories, and roadside reflectors which contribute to safe driving at night by clearly outlining the highway for a half-mile or more ahead.

Safety glass for our automobile windows and windshields which is made by sandwiching a sheet of tough, transparent plastic between two pieces of ordinary plate glass, is another gift of chemical research to our safety.

One interesting member of the plastics family is "Lucite," or methyl methacrylate resin, which is light in weight, nearly unbreakable, water-white and as transparent as optical glass. A remarkable property of Lucite is its ability to transmit light with very little loss of intensity. Long rods of Lucite can be bent into almost any shape; and, if a source of light is placed at one end, the light will come out at the other with nearly the same brightness. This ability to "pipe" light around corners makes Lucite very useful to the dentist, the surgeon, and others who need light in inaccessible places.

Laminated plastics, made by combining a number of sheets of plastic-filled cloth, paper or plywood under high pressure at high temperature, possess great strength and are used in making such articles as wall board, electrical instrument panels, radio cabinets, and gear wheels. In these uses they take the place of natural materials such as wood, steel and slate. Because laminated plastics are light as well as strong, airplane fuselages and even wings may be molded from them.

THE ROMANCE OF COAL TAR

Chemists are always studying the by-products, the seeming waste products, of industrial processes. When coal was treated in gas works and in coke ovens to produce gas and coke, there came off in the process a black, sticky substance. This was regarded as waste and was gotten rid of, often with considerable bother. But chemists worked in their laboratories on this coal tar. One day an English chemist's assistant, William Henry Perkin, washing the glass tubes after an experiment that had failed, noticed that the black sticky stuff from his tubes kept coloring the water purple. Out of so simple an observation made by a lad in his 'teens came the entrance into the great field of dyes made from coal tar. From the refuse of the gas works was created a new industry. In the commercial list of dyestuffs published in a recent year there were a thousand dyes made from coal tar.

What this releasing of a rainbow of colors from a thick, oily black fluid means in our lives, it is hard to estimate. If the only dyes available were vegetable dyes, the materials and foodstuffs which we handle would necessarily be deprived of much of their color, for the supply would be very limited. As it is, the chemist can see to it that our clothes are tinted in a thousand hues, that our houses are painted to any shade we desire, and that our bottled and canned goods are harmlessly treated with coloring matter which makes them more attractive. All dyes do not come out of coal tar, but it is the source of an incredible number of the tints that make up the color scheme of our daily lives.

Dyes likewise are not the only useful products derived from coal tar. Chemists have broken up this remarkable substance into its various elements, many of which are used in large quantities in the photographic industry and in the manufacture of perfumes, soaps, varnishes, lacquers, and explosives.

From its parts are prepared a long list of remedies and materials used in medicine. While these do not amount to much in quantity, their value in the fight against disease and pain and in the protection of human health cannot be measured.

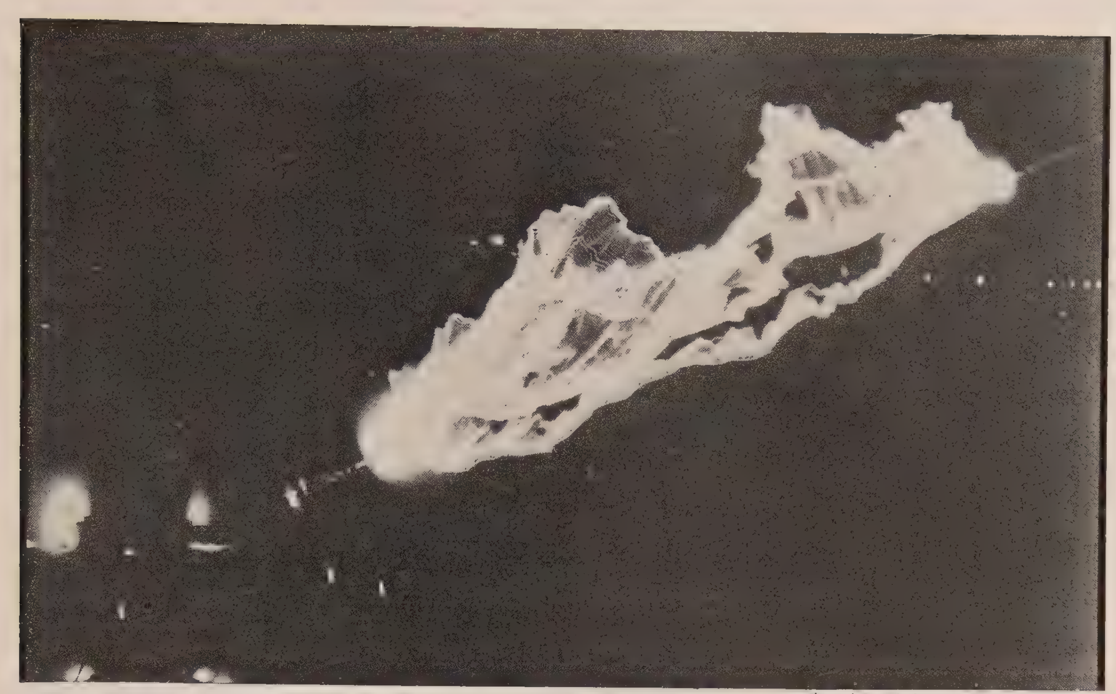
IN THE MINERAL FIELD, FUSED QUARTZ

Another discovery which the scientist rates high is the ability to handle successfully one of our most common minerals, quartz, in a way that makes it immensely valuable in many necessary operations.

Platinum has figured for many years as the "miracle metal" because of many properties which made it extremely useful in machinery. Among these are its low expansion, its easy workability, its great strength, its hardness, and its reactions in connection with certain chemical and electrical tests. But platinum is expensive because of its extreme scarcity. A new process, discovered in 1924, by which quartz could be fused in quantity, has turned this common mineral into a "miracle metal" which rivals the rare and expensive platinum in its all-round serviceability.

Let us make a list of some of these qualities with which fused quartz is found to be endowed, and then see how they are useful in everyday commercial undertakings. It has a hardness exceeding that of platinum. It has a transparency excelling that of glass, so that it has been called a "new glass," and this transparency extends to the realm of the ultra-violet rays, which are so useful in medical treatment of certain diseases. It tends to form an extremely smooth surface. It can be heated to almost unbelievable temperatures, and then plunged instantly into cold water without exhibiting any change. Glass and most other substances would crack instantly if they were put through a quick shift of temperature ranging from 3000 to 4000 degrees to 60 or 70; but fused quartz is utterly indifferent to the changes. Metals vary in their tendency to expand under changes of temperature or other atmospheric conditions. Fused quartz has only an infinitesimal variation. It will thus be useful in standards of length and in delicate machinery. Again, it is an extremely good electric insulator.

Pieces of fused quartz when handmade with an oxygen flame were worth several times their weight in gold. The discovery of a method of fusing it in quantity in an electric furnace, which should make it available for special work though still expensive, deserves to rank high among recent discoveries.



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ARTIFICIAL LIGHTNING, MAN-MADE IN A LABORATORY

This photo shows a flash of 1,500,000 volts crossing a gap of 14 feet. In this flash a force is released, for the fraction of a second, of more than ten million horse power.

SOME PROBLEMS OF TO-DAY

To tell in any one year on what problems chemists are engaged is perhaps venturesome beyond justification; yet it would seem that there are certain lines on which the thoughts of scientists are concentrated. One is the evolving of substitutes for certain vegetable products. An immense amount of wood pulp is used each year to supply the cellulose or plant fiber which is the basis for our paper and for kindred articles. We are cutting down our forests at an alarming rate for this purpose. So there is much research under way for a substitute for wood pulp in the manufacture of paper.

Our entry into World War II brought many new problems. One of the most pressing was the problem of our rubber supply. Until the war more than ninety per cent of the rubber used in the United States was imported from the East Indies. The Japanese conquests cut off this supply completely and our scientists were called upon to devise methods of producing artificial rubber and rubber substitutes quickly and in great quantities from materials available in our own country. While it was impossible to make up the shortage at once, practical methods of producing synthetic rubber from petroleum and also from grain alcohol were rapidly perfected and put into large scale operation.

It is a tribute to the discoveries of the past that manufacturers are taking more and more interest in the research work of the chemist. Most of the great industrial plants now maintain research laboratories where new methods are constantly being tried out. Research has brought about great savings through finding methods whereby the waste materials from manufacturing processes could be turned into salable by-products. In many cases the by-products, previously discarded, have proved of more value than the principal articles of manufacture themselves. The United States Government maintains an army of research workers, and the great medical foundations are always active in such investigation. There has never been a time when the health of our industrial workers has been so carefully studied or their work watched so that accidents may be prevented by safety devices.

THE FARMER AND THE SCIENTIST

The farmer faces one of the most constant and definite of chemical problems. Growing plants take certain substances from the soil. The soil must have these ingredients fed back into it if subsequent crops of plants are to find the needed food. The farmer of olden times used to apply manure to his fields and to plough in certain crops, knowing that it improved his future crops but without much idea of the reason. Now he knows that these were successful fertilizers because they supplied certain needed substances, notably nitrogen and potash. A nitrogen supply is an essential for an agricultural nation, and one of the triumphs of modern chemistry has been its splendid achievement in making use of the nitrogen in the air.

NITROGEN FIXATION

Until 1914 nearly all the nitrates and nitric acid used in the manufacture of fertilizers and explosives had come from the nitrate beds of Chile. Over two million tons of nitrate were obtained from these deposits every year, and it was taken for granted that the supply would continue accessible to all nations. The World War changed all this. Each nation set to work to manufacture as best it could the nitrates required for war purposes and fertilizers.

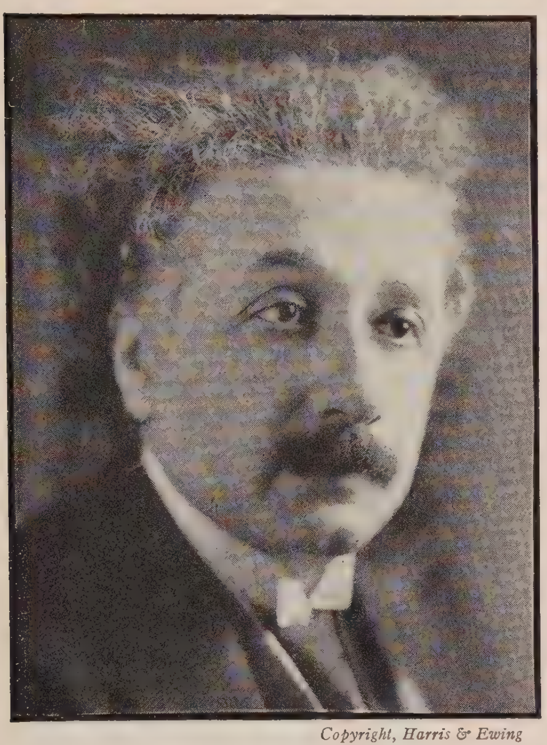
Chemists attacked the problem of nitrogen "fixation," that is, the problem of changing some of the inexhaustible store of nitrogen in

Photo, Ewing Galloway

PUMPKIN FIELD

Yielding good second crop after application of fertilizer to the soil.

the atmosphere into useful nitrogen compounds. The problem was a difficult one for free nitrogen is an inert gas which does not readily unite with other common chemical elements. However, the chemists proved equal to their task. The first nitrogen fixation process they developed was known as the arc process. In this process air is blown into a powerful electric discharge, or electric arc, which causes some of the nitrogen and oxygen in the air to unite. The nitrogen oxides thus secured are drawn through water, and the solution of nitric acid is run upon soda to produce sodium nitrate, or upon lime to produce calcium nitrate. These fertilizers fully equal the natural Chilean nitrates. The cheap production of nitrates is possible wherever sufficient water power can be had to generate electricity at low cost. During the World War our government spent more than one hundred million dollars to build Wilson Dam and two huge nitrate plants at Muscle Shoals, Alabama. (See Volume Four, pages 383 and 388). Norway, too, has enormous water power and that country now produces artificial nitrates on an immense scale.



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DR. ALBERT EINSTEIN

German scientist, whose theory of relativity is an outstanding contribution to scientific and philosophic thought.

In this country, however, the arc process has been little used since about 1930, having been displaced by newer methods of nitrogen fixation known as the synthetic ammonia process and the cyanamid process. With the government's plant at Muscle Shoals held in reserve for use in case of war emergency and with large commercial plants operating constantly, the United States is today well supplied with nitrogen fixation plants to meet all its needs.

THE STRUCTURE OF MATTER

Within the last few years the investigations of science have brought to us an entirely new idea of the composition of matter and of the universe in which we live. Matter had always been considered solid, impenetrable, and incapable of change except through rearrangement of its molecules or atoms. Research has changed all that, and we now know that the tiny atom itself is made up of still smaller particles called "protons" and "electrons." This fact helps to explain in marvelous manner many familiar everyday phenomena, such as the passage of an electric current along a wire, and promises to unlock many of the riddles of science. In the story "Worlds Within Worlds" in Volume X, page 308, you will find an interesting explanation of the molecule, atom, and electron.

MAN AND THE UNIVERSE

While the scientist is concerning himself with the study of these tiniest of particles, he is also peering into space and dealing with distances so great that they can only be reckoned in "light years," or the distance which light would cover in a year of time. To gain a faint idea of the tremendousness of such a distance, figure out for yourself the number of seconds in a year and multiply it by 186,000, which is the number of miles light travels in a sixtieth of a minute. From his mathematical studies of the universe the scientist develops intricate and bewildering theories of time and space. Dr. Albert Einstein, for instance, brings forth a theory of relativity in which he showed the two to be related in ways that open to philosophers a new world of thought.

While the world still marveled at the power of the mind of man to journey into the unknown, Dr. Robert Andrews Millikan, a Nobel prize winner and famous American scientist, journeyed to mountain tops to make studies of a new kind of ray, detected by himself and other scientists, both in the United States and abroad, as coming from the far reaches of the universe and producing unexplained effects on their delicate scientific instruments. Dr. Millikan's studies, also studies by Dr. Arthur H. Compton, another Nobel prize winner, have shown that these rays do not come from our sun but from far out in the universe. Hence they are called "cosmic" rays from the word "cosmos" which means the universe. The study of cosmic rays has been extended into the stratosphere, that region far above wind and cloud into which man is only beginning to penetrate. Instruments sent up in small passengerless balloons and in craft manned by daring scientists have brought back records of these rays which show them to be of extremely short wave length—the shortest of any known waves—and powerful enough to penetrate eighteen feet of solid lead. (For an interesting story of balloon ascents into the stratosphere turn to Volume Four, page 390.)

PIONEERING

Most interesting of all is the pioneering which is being carried on as to the essence of all matter and the laws which control its action. As we have seen in our study of fuel and of electricity, the cry of the world is for energy. When, therefore, a physicist succeeds in making artificial lightning in his laboratory, he is doing more than imitate Nature for the sake of seeing that he can do it. In this man-made flash of lightning a force is released for a fraction of a second which is more than ten million horse power, or greater than that of any power plant in the country. When he succeeds in dispelling a fog by spraying into it electrically charged grains of sand, he is producing on a small scale an effect on the weather which may be of far-reaching importance.

Even the tiny atom itself is now the target of scientists who are trying to break it up into the even tinier electrons and protons of which it is composed. What success in this endeavor will mean is unknown even to the men who are delving into its mysteries. It may reveal a new source of power, beneficial to all mankind. It may unleash destructive forces, useless because of inability to control them. The possibilities hidden in this field of experiment are staggering even to the most vivid imagination.

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DR. ROBERT A. MILLIKAN

Noted American scientist, who has made great contributions to the knowledge concerning the structure of matter.

This is but one of the many unknown worlds about us into which the explorers and pioneers of science are slowly making their difficult way.

The research of to-day provides the inventions of to-morrow; the inventions of to-day are translated into practical commercial use in the industries of to-morrow. All find their source in that spirit breathed into man

"Lifting him up from his low estate,
With masterful passion, the wish to create."

F.R.HARPER